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Scallop Production Areas in the Bay of Fundy: Stock Status for 2008 and Forecast for 2009

Zones de production du pétoncle dans la baie de Fundy: état du stock en 2008 et prévisions pour 2009

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Abstract

This document reviews the status of scallop stocks in Scallop Production Areas (SPAs) 1, 2, 3, 4, 5, and 6 (Bay of Fundy and Approaches) for 2007/2008 with advice for the fisheries in 2008/2009. In SPA 1A landings were 225 t for the Full Bay Fleet during the 2007/2008 fishing year against a quota of 216 t. An interim TAC of 120 t was set for the 2008/2009 season based on the 2007 assessment advice. Recent commercial catch rates have been stable around the median. The only sign of above average recruitment is in the 8 to 16 mile area. Population biomass estimated to be 1426 t (meats) in 2008, has increased over the estimate for 2007 (1408 t) and is above the median biomass of 1246 t (1997 to 2007). Catches of 196 to 265 t for 2008/2009 should result in a small increase in biomass for 2009. However, the population model has a tendency to overestimate the commercial size population when forecasting ahead and catches in the upper part of this range may actually result in a small decrease in biomass.

The Full Bay Fleet landed 210 t against a total quota of 206.25 t over all three subareas in SPA 1B. Landings for the Mid Bay fleet were 120 t in total against a TAC of 148.28 t for SFA 28B and SFA 28C. The TAC for SFA 28C and 28D was 85.47 t for the Upper Bay fleet and they landed 87 t in total for 2008. An interim TAC for 2008/2009 was set at 100 t for the Full Bay fleet. Commercial catch rates have been increasing for all three fleets since 2006 mainly due to better than average recruitment in the Cape Spencer, Middle Bay North (Quaco Ledge) and SFA 28C area. The increase for the Upper Bay Fleet in 2008 was partly due to fishing in the small but very productive Advocate area of SFA 28D. Survey estimates in the SFA 28B, 28C and Advocate Harbour areas (28D) indicate above average densities of scallops in the 40 to 64 mm size range in 2008. Population biomass estimated to be 1890 t (meats) in 2008 has increased slightly over the estimate for 2007 (1864 t) and is above the median biomass of 1638 t (1997 to 2007). Catches for 2008/2009 of 290 t or less should not result in a decline in biomass for 2009. Recruitment prospects look much better for 2009/2010 and the incoming year-class will be commercial size for the 2010/2011 fishery.

Total landings in SPA 3 for the 2007/2008 fishing year were 80 t against a TAC of 70 t. An interim TAC of 50 t was set for October of the 2008/2009 fishing season. Commercial catch rate has been stable and close to the median over the time series since 2006. Comparison of differences between survey estimates from the 2007 and 2008 surveys indicated significant decreases in mean numbers per tow of recruits and mean weights per tow of commercial size scallops and recruits. Population biomass estimated to be 463 t in 2008 has decreased over the estimate for 2007 (531 t) and is below the median biomass of 655 t (1996–2007). The commercial size biomass is predicted to decrease from 2008 to 2009 if the interim quota of 50 t was caught. Recruitment is expected to be low for at least the next two years.

In SPA 4, total landings in 2007/2008 were 79 t against a TAC of 100 t. An interim TAC of 100 t was set for the 2008/2009 season was based on last year's assessment. Commercial catch rates declined after the above average 1998 year class recruited to the fishery but have been either

relatively stable or slightly increasing since 2005/2006. Population biomass estimated to be 779 t (meats) in 2008 has increased over the estimate for 2007 (760 t) and is just below the long-term median biomass of 792 t (1983 to 2007). A TAC of 100 t for 2008/2009 should result in little change in the population biomass of commercial size scallops for 2009.

Landings in 2008 for SPA 5 were 7 t against a TAC of 10 t. Commercial catch rates in 2008 increased over 2007 and were close to the long-term median levels (1977–2007). Survey shell height frequencies indicate that the 2007 year-class may be the strongest seen since the 1999 and 2000 year-classes. Currently, the survey mean catch per tow for commercial size scallops is below the long-term median and close to the lowest seen in this series. The TAC for 2009 should not exceed the average catch of 9 t over the period 1997 to 2008 excluding the high catch in 2004. Good recruitment prospects may improve the stock status in 2010.

The combined landings in SPA 6 for 2008 for the Full Bay and Mid Bay fleets were 68 t against a TAC of 140 t. Both catch and catch rates for both fleets have been relatively stable over the last four years. Comparison of survey estimates from 2007 and 2008 suggests there has been little change in mean numbers per tow of commercial size scallops in 6A, 6B or 6C. Recent levels of catch do not appear to result in a decrease in the population abundance of scallops in the SPA 6 area as a whole.

Resumé

Le présent document traite de l'état des stocks de pétoncle dans les zones de production de pétoncle (ZPP) 1, 2, 3, 4, 5 et 6 (baie de Fundy et approches) en 2007/2008 et donne les avis pour les pêches en 2008/2009. Dans la ZPP 1A, les débarquements de la flottille de la totalité de la baie de Fundy se sont chiffrés à 225 t en 2007/2008, par rapport au quota de 216 t. Un TAC provisoire de 120 t a été fixé pour la saison 2008/2009 d'après l'avis donné pour 2007. Les récents taux de capture commerciale sont stables et se situent alentour de la médiane. Le seul signe de recrutement au dessus de la moyenne se trouve dans le secteur de 8 à 16 milles. La biomasse de la population, estimée à 1 426 t (tonnes de chairs) en 2008, a augmenté par rapport à l'estimation pour 2007 (1 408 t) et se situe au dessus de la biomasse médiane de 1 246 t (1997–2007). Des prises de 196 à 265 t en 2008/2009 devraient résulter en une légère augmentation de la biomasse en 2009. Toutefois, le modèle de population a tendance à surestimer les effectifs futurs de la population de pétoncles de taille commerciale. Des prises se chiffrant dans la partie supérieure de cet écart pourraient en fait résulter en une faible baisse de la biomasse.

Les débarquements de la flottille de la totalité de la baie se sont chiffrés à 210 t, par rapport à un quota total de 206,25 t pour les trois secteurs de la ZPP 1B. Les débarquements de la flottille du milieu de la baie se sont chiffrés à 120 t, par rapport au TAC de 148,28 t pour les ZPP 28B et 28C. La flottille de la partie supérieure de la baie disposait d'un TAC de 85,47 t dans les ZPP 28C et 28D; elle en a débarquées 87 t au total en 2008. Un TAC provisoire de 100 t a été attribué à la flottille de la totalité de la baie pour 2008/2009. Les taux de capture commerciale des trois flottilles sont à la hausse depuis 2006, en grande partie à cause du recrutement supérieur à la moyenne dans les secteurs du cap Spencer et du milieu de la baie nord (chaussée Quaco), ainsi que dans la ZPP 28C. L'accroissement du taux de capture observé en 2008 chez la flottille de la partie supérieure de la baie est attribuable en partie au fait qu'elle a pêché dans le secteur Advocate Harbour, petit mais très productif, de la ZPP 28D. Les estimations, d'après les résultats des relevés, des densités de pétoncles dans la ZPP 28B, la ZPP 28C et le secteur Advocate Harbour (28D) indiquent que les densités des individus de 40 à 64 mm sont supérieures à la moyenne en 2008. La biomasse de la population, estimée à 1 890 t (tonnes de chairs) en 2008, a augmenté légèrement par rapport à l'estimation pour 2007 (1 864 t) et se situe au dessus de la biomasse médiane de 1 638 t (1997–2007). Des prises de 290 t ou moins en 2008/2009 ne devraient pas entraîner un déclin de la biomasse en 2009. Les perspectives de recrutement pour 2009/2010 sont très bonnes et la classe d'âge à venir sera de taille commerciale pour la saison 2010/2011.

Le total des débarquements provenant de la ZPP 3 en 2007/2008 s'est chiffré à 80 t, par rapport à un TAC de 70 t. Un TAC provisoire de 50 t a été établi pour octobre de la saison 2008/2009. Le taux de capture commerciale était stable et se situe près de la médiane de la série chronologique depuis 2006. La comparaison des différences entre les estimations d'après les relevés effectués en 2007 et 2008 révèle des baisses marquées du nombre moyen de recrues par trait et du poids moyen des pétoncles de taille commerciale et des recrues par trait. La biomasse de la population, estimée à 463 t en 2008, a diminué par rapport à l'estimation pour 2007 (531 t); elle est inférieure à la biomasse médiane de 655 t (1996–2007). On prévoit que la biomasse de pétoncles de taille commerciale diminuera entre 2008 et 2009 si le quota provisoire de 50 t est récolté. On s'attend à ce que le recrutement soit faible durant les deux prochaines années au moins.

Dans la ZPP 4, le total des débarquements en 2007/2008 s'est chiffré à 79 t, par rapport à un TAC de 100 t. Un TAC provisoire de 100 t a été établi pour la saison 2008/2009 en fonction de l'évaluation de l'an dernier. Les taux de capture commerciale ont diminué après que la classe d'âge 1998, d'abondance supérieure à la moyenne, ait été recrutée à la pêche, mais ils sont soit relativement stables ou légèrement à la hausse depuis 2005/2006. La biomasse de la population, estimée à 779 t (tonnes de chairs) en 2008, a augmenté par rapport à l'estimation pour 2007 (760 t) et se situe juste au dessous de la médiane à long terme de 792 t (1983–2007). Un TAC de 100 t pour 2008/2009 devrait se traduire par peu de changement dans la biomasse de la population de pétoncles de taille commerciale en 2009.

Les débarquements provenant de la ZPP 5 en 2008 se sont chiffrés à 7 t, par rapport à un TAC de 10 t. Les taux de capture commerciale en 2008 ont augmenté par rapport à 2007, pour se situer près de la médiane à long terme (1977–2007). Les fréquences des hauteurs de coquille dans les relevés indiquent que la classe d'âge 2007 est peut être la plus abondante depuis les classes d'âge 1999 et 2000. Les prises moyennes de pétoncles de taille commerciale par trait de relevé se situent actuellement au dessous de la médiane à long terme et près des niveaux les plus faibles de la série. Le TAC pour 2009 ne devrait pas être supérieur aux prises moyennes de 9 t pour la période 1997–2008, à l'exclusion des prises élevées de 2004. De bonnes perspectives de recrutement peuvent mener à une amélioration de l'état du stock en 2010.

Les débarquements combinés en 2008 des flottilles de la totalité et du milieu de la baie provenant de la ZPP 6 se sont chiffrés à 68 t, par rapport à un TAC de 140 t. Les prises et les taux de capture des deux flottilles au cours des quatre dernières années ont été relativement stables. La comparaison des estimations d'après les relevés effectués en 2007 et 2008 donne à penser que le nombre moyen de pétoncles de taille commerciale par trait a peu changé dans les ZPP 6A, 6B et 6C. Les niveaux des prises récents ne semblent pas résulter en une baisse de l'abondance des pétoncles dans l'ensemble de la ZPP 6.

Introduction

The Bay of Fundy is fished by three separate scallop fishing fleets. Full Bay scallop license holders are able to fish scallops anywhere in the Bay of Fundy, Mid Bay license holders can fish for scallops on the northern side of the Mid Bay line (Fig. 1) and Upper Bay license holders fish east of the Upper Bay line. The Full Bay fleet has traditionally been based in Digby with larger vessels (>14.5 m and <19.8 m Length Over All (LOA)) fishing only scallops, the Mid Bay fleet consists mainly of New Brunswick based, smaller (<14.5 m LOA) vessels with multiple licenses for different species, and the Upper Bay fleet are Nova Scotian and New Brunswick based smaller, multi-species vessels. These distinctions are diminishing as the Mid and Upper Bay fleets become more specialized, and smaller boats are replaced with larger ones. The Full Bay fleet fishes under Individual Transferable Quotas (ITQs) with a 1 October to 30 September season while the Mid and Upper Bay fleets fish a competitive quota with a 1 January to 31 December season.

Details on areas, fleet access, current TACs, landings and available data sets for stock assessment are given in the table below. No TAC has been set for SPA 2 and fishing can take place subject to special licence conditions. The Decision column indicates whether advice is provided in terms of a formal model or simply on the basis of trends in the abundance indices.

SPA	Fleets	TAC (meats, t)	Landings[1] (meats, t)	Survey (strata)[2]	CPUE	Decision
1A	Full Bay	216.0	225.0	1981–2008 (8–16) 1984–2998 (2–8 mile) 1997–2002, 2004–2008 (MBS)	1976–2008	Model
1B	Full Bay	206.25	210.0	1997–2008 (Cape S., MBN)	1982–2008	Model
	Mid-Bay	148.28	120.0	2002–2003, 2005–2008 (UB)	1992–2008	
	Upper Bay	85.47	87.0		1997–2008	
2	Full Bay			2006		Marginal
	Mid-Bay					Area
3	Full Bay	70.0	80.0	1996–2008	1996–2008	Model
4	Full Bay	100.0	79.4	1981–2008	1976–2008	Model
5	Full Bay	10.0	7.0	1997–2008	1976–2008	Trends
6	Full Bay	21.0	7.4	1997–2003, 2004–2008	1976–2008	Trends
	Mid-Bay	119.0	60.6		1993–2008	
	All	976.0	876.4			

1. As of November 28, 2008.

2. Survey strata are given in Fig. 2

The total number of stations covered in the Bay of Fundy and Approaches in 2008 was 754, an increase over the number from 2007 (702) and above the number of stations in recent previous years (520 to 645). Fishing industry representatives agreed to help fund DFO overtime shortfalls in 2008 to maintain the survey coverage to be close to the 2007 level for SPA 1A, 1B, 3 and 4. Continuing support in future years by industry will be contingent upon evaluation of the results, further discussion about the purpose of the survey and the development of an equitable method of sharing the costs amongst industry participants. Funds from the Petitcodiac Causeway project were used to add additional stations to the Upper Bay area as part of the monitoring associated with plans for the opening of the causeway in 2010.

In this document, we present the scientific advice for the 2008/2009 Full Bay scallop fleet season and the 2009 season for the Mid-Bay and Upper Bay scallop fleets. Data used for the analyses came

from commercial fishing logs and dockside monitoring documents, samples of meat weights in the catch, and independent research vessel surveys. Details on these sources of data, survey protocols, and their analyses are available in Roddick (2002), Roddick and Butler (2002), Smith and Lundy (2002a), Smith and Lundy (2002b) and Smith et al. (2008).

Annual scallop population surveys

Fisheries management has requested stock advice for subareas of SPA 1B and new strata areas were defined, e.g., Spencer's Island, Scots Bay, to meet this demand (Fig. 2). In addition, the definitions for all of the strata in the Bay of Fundy area were re-evaluated in terms of lining up boundaries to coincide with the management areas. Inconsistencies between strata definitions in the survey database and the assignment of survey stations to strata were discovered and the completion of the stock assessment had to be delayed until these problems were dealt with. The locations of survey tows from 1981 to the present were plotted on a GIS system and reassigned to the new revised strata making it easier to access data on any spatial area required.

The 2008 survey coverage and spatial distribution for the different size classes and clappers in the Bay of Fundy area are presented in Figures 3–6. There appear to be only two areas of high densities of recruits (65–79 mm shell height) for the 2009 fishery; however, there are some promising areas of high densities of pre-recruits (< 65 mm) in the 8 to 16 mile portion of SPA 1A, Cape Spencer and the Upper Bay areas. Clappers were generally found in low densities throughout the Bay. Similar figures for the Brier/Lurcher area (SPA 3) and Grand Manan (SPA 6) are presented later on in this document.

In the past, changes in meat weight/shell height relationships have been monitored by tracking the expected meat weight for scallops with shell height equal to 100 mm in the surveys for each of the scallop production areas. This year, this reference level meat weight has shown declines in all areas except for Cape Spencer in SPA 1B, SPA 4 and SPA 5 (Fig. 7). The highest declines were observed in SPA 3 and SPA 6.

Population model and decision rules

The population dynamics for all SPAs except for 5 and 6 were modelled using the delay-difference model,

$$B_{t+1} = s_t \left(\rho + \frac{\alpha}{\bar{w}_t} \right) B_t + R_t, \tag{1}$$

where B_t, $\bar{w}_t$, and s_t are the population biomass, average weight of the portion of the population recruited to the fishery and the survival from both fishing and natural mortality, respectively in year t. The term R_t denotes the biomass of the recruiting size classes in year t. The $\rho + \alpha/\bar{w}_t$ term is the annual growth increment and will decrease (increase) as the average size increases (decreases) representing an older slower growing (younger, faster growing) population. The parameters α and ρ are obtained from a regression of the weights-at-age a on the weights-at-age $a - 1$. This linear relationship is a consequence of using a von Bertalanfy growth curve for weight as a function of age (Quinn and Deriso 1999).

The total survival rate is assumed to be the product of natural survival rate and the harvesting rate. With catch known, the model in 1 can be written as,

$$B_{t+1} = \left(\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)(B_t - C_t) + R_t\right)\mu_t, \tag{2}$$

where m_t represents instantaneous natural mortality and C_t is the catch in year t. The μ_t denotes a random error associated with the model dynamics. The state-space structure of the model and the Bayesian methods for estimation were reviewed in last year's document (Smith et al. 2008).

Current practice within the Department of Fisheries and Oceans is to define reference points to be used for decision rules with respect to evaluating removal levels or harvest rates (DFO 2006). Development of reference points for the inshore scallop fisheries to-date were reviewed in Smith et al. (2008).

Since 2004 an heuristic approach based upon the estimated exploitation rates and the associated changes in biomass for various stocks over the periods covered by the assessment model has been used to set an exploitation rate reference point for scallops (DFO 2004). Exploitation rates were calculated as catch divided by the biomass at the beginning of the fishing season. Excluding those years where episodic recruitment occurred, the general finding for SPA 1A, 1B, 3 and 4 was that population biomass almost always increased following an exploitation rate of less than 0.2, while population biomass would almost always decrease following exploitation rates higher than 0.2 (Smith et al. 2008). Potential catch levels for future fishing seasons were evaluated against this rate of 0.2 using the delay-difference model by determining the posterior probabilities of exceeding 0.2.

This approach of using 0.2 for all areas ignored the differences in growth potential between years, differences in natural mortality rates between areas and the impact of recruitment on increasing biomass over the fishing season. In addition, estimation of the exploitation rate associated with a specific catch by dividing catch by biomass prior to the fishing season also ignores losses due to natural mortality and gains due to growth and recruitment over the fishing season.

In this assessment, we have refined the definition and evaluation of exploitation rates to overcome the problems listed above. In the first place, exploitation rates are now estimated by dividing the catch in year t by the biomass in the following year plus the catch in year t. The biomass in the following year will include all of the gains and losses due to natural mortality, growth and recruitment over the fishing year and hence when catch is added back in, accounts for the productivity of the stock. As a result, years with high or low recruitment levels can be handled in the same way.

Exploitation rates are compared with the expected increase in the population biomass due to growth discounted for natural mortality. This increase is calculated as $\exp(-m_t)(\rho + \alpha/\bar{w}_t)$ from the model (equation 2). The growth potential of the commercial size biomass decreases as the size of the adults, measured by the average meat weight $\bar{w}_t$, increases. The exploitation level at which the commercial size biomass stays the same between year t and $t+1$ (ignoring recruitment) can be derived as follows by substituting exploitation rate times biomass for catch ($e_t \times B_t = C_t$).

$$
\begin{aligned}
B_{t+1} &= \exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)(B_t - C_t) \\
B_{t+1} &= \exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)((1 - e_t)\,B_t) \\
B_{t+1} &= (1 - e_t)\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)B_t
\end{aligned} \tag{3}
$$

Setting $B_{t+1} = B_t$ implies,

$$
\begin{aligned}
(1 - e_t')\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right) &= 1 \\
(1 - e_t') &= \frac{1}{\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)} \\
-e_t' &= \frac{1 - \exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)}{\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)} \\
e_t' &= \frac{\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right) - 1}{\exp(-m_t)\left(\rho + \frac{\alpha}{\bar{w}_t}\right)}
\end{aligned} \tag{4}
$$

The solution in equation 4, e_t' is referred to here as the replacement level. Assuming no recruitment, exploitation rates above this level of expected increase will result in a decline in biomass while exploitation rates below it will result in increases in population biomass purely due to growth. If catch levels result in exploitation above the expected increase, then declines in population biomass wil. occur unless compensated for by recruitment.

Recruitment can add biomass to the population in two ways. First there is the initial increase in biomass due to the animals growing into harvestable size. Additionally, increasing recruitment will tend to decrease the average meat weight of commercial size scallops as more younger smaller animals recruit and in turn will increase the growth potential of the commercial size portion of the population. Further details on this approach will be introduced when the status of populations in each of the SPAs are discussed.

SPA 1A: Southwest Bay of Fundy

Commercial fishery

Maps of fishing locations based on commercial fishing logs for the Full Bay fleet are presented in Figure 8 for the last four seasons in SPA 1A, 1B and 4.

The 2007/2008 quota for the Full Bay Fleet in SPA 1A was initially set at 190 t. This was up from 150 t in 2006/2007 and below the average (1997–2007) of recent landings (Fig. 9). The industry requested a re-evaluation of the quota in the summer of 2008 based upon recent catch rates and the quota was increased to 216 t based upon the decision table from the 2007 assessment. This quota corresponded to the catch for which there was a 50 percent probability of exceeding the 0.2 exploitation reference point. Landings were 225 t for 2007/2008. An interim TAC of 120 t was set for the opening of the 2008/2009 season.

Year	Avg. 99–03[1]	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008[2]	2008/ 2009
TAC (t)	NA	700	400	100	150	216	120[3]
Landing (t)	303	467	321	160	137	225	6[4]

[1] Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003. Quotas prior to 2002 are not applicable here and landings for 1998–2001/2002 are for SPA 1A only.

[2] landings based on 2007/08 quota report dated 28 November 2008.

[3] interim TAC.

[4] landings based on 2008/09 quota report dated 26 November 2008.

Catch rates have been stable around the median catch rate over the 1995/96 to 2007/08 period (Fig. 10). Fishing effort declined from 2002/03 to 2006/07 as the strong 1998 year-class, which was mainly found in the 8 to 16 mile area (Figs. 1 and 2, strata 11 to 20), was fished out. While effort did increase in 2007/08 it is still at a lower level than through most of the preceding years in the series.

There were fewer meat weight samples obtained in the 2007/2008 fishing compared to the last two years (Table 1). Fishing effort in SPA 1A tends to be concentrated in the April to July period in recent years during a time period when average meat weights are declining due to both incoming recruitment and the transfer of energy from somatic growth to gamete production prior to spawning in August/September. However in 2006 and 2007 more fishing took place in the fall when higher meat weights occur in the fishery. As is true of all scallop areas, year-to-year changes in catch rate can be affected by changes in the seasonal distribution of effort given the seasonal patterns in meat weights.

Survey

Recruitment has been low in the 8 to 16 mile area (Fig. 2, strata 11 to 20) since the above-average 1998 year-class recruited to fishery (Fig. 11), note change in scale for y-axis after 2002). In the 2007 there were higher than average densities of scallops in the 20 to 40 mm range observed in the survey, mainly along the SPA 4 border. These densities appear to still be there but they were patchy in distribution (Fig. 5). While these densities of small scallops appear to be higher than in previous years, they are not as high as was observed for the 1998 year-class at the same size. Overall, mean numbers per tow for commercial size (80 mm shell height), recruits (65 to 79 mm) and pre-recruits (< 65 mm) in 2008 have increased slightly over the survey estimates in 2007 (Fig. 12). Clappers remain at a low level relative relative to the catastrophic mortality event in 1989/1990.

Densities in the 2 to 8 mile area of SPA 1A (Fig. 2, Strata 6 and 7) are much lower than those in the 8 to 16 mile area (Fig. 13). There is some evidence of recent increases in recruits and pre-recruits (Fig. 14). Clappers remain low relative to previous years.

Recent survey coverage of the area now referred to as Middle Bay south (Fig. 2) was reviewed in Smith et al. (2008). There was no survey coverage in this area for 2003 and 2004. Since 2005, the population of commercial size scallops have been fished down while there has been a low level of steady recruitment (Figs 15 and 16).

Population model

The delay-difference model was fit to survey biomass estimates from all three areas and catches from SPA 1A from 1997 to 2008. Survey biomass was calculated by converting numbers-at-shell height to weight-at-shell height using meat weight/shell height relationships. Meat weight/shell height data was available from all of the areas in SPA 1A, while meat weights and ages were only available in 2006 and 2007 from all of the areas. Model diagnostics based on the posterior predictive distributions indicate that the model fits the data quite well as all of the probabilities of drawing a more extreme observation from the marginal posterior distributions are very close to 0.5 and do not exceed the 0.025 and 0.975 bounds for extreme values (Fig. 17). An evaluation of the performance of the model with respect to estimating and forecasting biomass shows that while there is a slight tendency for over-estimation in recent years, there is no disagreement in overall trend (Fig. 18).

Stock status and forecast

Commercial size biomass has been increasing since 2005 with moderate to low recruitment (Fig. 19a). The main reason for this increase appears to be exploitation levels less than or close to the expected levels due to growth discounted for natural mortality (designated as the replacement line in Fig. 19b). Note that the biomass declined for 1998 even though the exploitation rate was below the replacement line and a biomass increase was indicated for 2002 when the exploitation rate was above the line. In the former case, the decrease from 1997 to 1998 was extremely small and probably within the range of variation of the population estimates. The 2002 population increased despite the higher exploitation rate because of the recruitment of the larger than average 1998 year-class plus a stronger than expected growth rate (Smith et al. 2003).

The interim TAC of 120 t results in an exploitation level below the replacement line and an increase in population biomass is indicated for 2009. The average meat weight of the commercial size biomass has been increasing since 2007 as the average age of this portion of the biomass increases along with relatively low levels of recruitment. With increasing average meat weight (and age), there is less compensation to impact of fishing due to growth and lower exploitation levels will be needed to keep the population biomass from declining. At present none of the subareas in SPA 1A are showing signs of strong year-classes for 2009 or 2010.

In previous documents (e.g., Smith et al. 2008) a range of catch levels in the upcoming season are evaluated in terms of the probability of the resultant exploitation rate exceeding 0.2 determined using the posterior distribution from the delay-difference model. In this year's document we have re-orientated the table to present a range of catches and median exploitation rates for 2008/2009 along with the resulting expected changes in commercial size biomass between 2008 and 2009 (Table 2).

Catches from 196 to 265 t for 2008/2009 should result in a small increase in biomass for 2009 (Table 2). However, the model has a tendency to overestimate the commercial size population when forecasting ahead (Fig. 18) and catches in the upper part of this range may actually result in small decreases in biomass.

As before, catch levels in the following year (i.e., 2009/2010) are evaluated for each of the catch levels listed for the upcoming year (2008/2009). As discussed earlier, exploitation rates are now calculated with respect to the end of season biomass for the upcoming year (2009) but are still estimated using beginning of year biomass for the following year because we do not know the average meat weight or expected recruitment for 2009/2010. These quantities can only be estimated from the survey data in 2009. Therefore, the estimated catch levels for 2009/2010 are conservative and are meant to provide guidance for interim TACs to be set for October 1 2009. These catch levels will be refined when the 2009 surveys are analysed in next year's stock assessment.

SPA 1B: Northern/Upper Bay of Fundy

Commercial fishery

Scallop production area 1B encompasses Scallop Fishing Areas (SFA) 28B (excluding SPA 6), 28C and 28D (Fig. 1). The Full Bay fleet can fish in the whole of 1B (Fig. 8), while Mid-Bay has quota only in 28B and 28C (Fig. 20), and Upper Bay can only fish in 28C and 28D (Fig. 21). In 2007/2008 a sharing formula was used for the first time to apportion the TAC over the three fleets that fish this area. The Full Bay fleet landed 210 t against a quota of 206.25 t. The Mid and Upper Bay fleets landed 155 and 87 t against quotas of 148.28 and 85.47 t, respectively (Fig. 22).

Full Bay

Year	Avg. 98–03[1]	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008[2]	2008/ 2009
TAC (t)	NA	200	200	225	200	206.25	100[3]
Landing (t)	181	211	228	144	213	210	11[4]

[1] Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003. Quotas prior to 2002 are not applicable here and landings for 1998–2001/2002 are for SPA 1B only.

[2] landings based on 2007/08 quota report dated 28 November 2008.

[3] interim TAC.

[4] landings based on 2008/09 quota report dated 26 November 2008.

Mid and Upper Bay

Year	Avg. 98–03	2004	2005	2006	2007	2008[2]
TAC (t)						148.28
MB: Landing (t)	59	177	155[1]	137	93	120
TAC (t)						85.47
UB: Landing (t)	21	87	50	48	79	87

[1] Remaining quotas in SPAs 1 and 6 combined 2 August 2004 with most of the combined quota coming from SPA 1.

[2] landings based on 2007/08 quota report dated 28 November 2008.

Commercial catch rates have been increasing for all three fleets since 2006 mainly due to better than average recruitment in the Cape Spencer, Middle Bay North (Quaco Ledge) and SFA 28C area (Figs 2 and 23). Effort has also been rising since 2002/2003. The sharp change in the Full Bay effort series reflects the concentration of fishing effort on the 1998 year-class in SPA 1A and 4 from 2001 to 2003. In the individual subareas, catch rates are comparable in 28B and 28C and higher in 28D (Fig. 24). In the latter case, fishing was mainly concentrated in the small but very productive Advocate area (Figs. 2, 8 and 21).

Meat weight sampling provided reasonable coverage for the Upper Bay fishery but there were far fewer samples collected from the Mid and Full Bay fleets in 2008 compared to previous years (Tables 3, 4 and 5). Generally, the samples show the decline in meat weights over the winter months, as the glycogen stores in the adductor muscle are used to carry the scallops through until the spring bloom of plankton. While there is year-to-year variation and incomplete sampling the general decline in meat weight is evident over the summer as gametes are produced in preparation for spawning in August/September. In recent years the Mid and Upper Bay fleets partition their quota into a winter fishery and late summer fishery. In 2008, the Upper Bay had caught most their quota during the winter fishery. The Full Bay fleet fishes year-round but the larger part of the effort usually occurs in August/September. Further study will be needed to understand the impact of seasonal patterns of fishing effort and meat weight trends on interpreting commercial catch rates.

Survey

The survey area for SPA 1B is comprised of the Cape Spencer and Middle Bay North areas in SFA 28B and the 28C and 28D area of Upper Bay (Fig. 2). Last year for the inshore Scallop Advisory Committee meeting, Fisheries Management requested separate estimates of biomass for 28B, 28C and 28D to apply their sharing formula for TACs. We were unable to model the population at such a fine scale and proposed using the distribution of survey biomass by area as a proxy. However, at the time it was difficult to estimate how much of the area of SFA 28D should be defined to be scallop grounds. In the 2008 survey, five subareas in SFA 28D were defined and survey stations were assigned to all areas (Fig. 2). Based on the results of the 2008 survey and comparison of results from previous surveys in the area, we determined that the area labelled 28D Inner along with the southern portion of 28D Outer (see Fig. 3) were marginal for scallops and should not be included for estimating biomass.

In addition, based upon surveys in the Middle Bay North area the distribution of scallops generally clustered in areas near the Cape Spencer area, on and near Quaco ledge and next to the SFA 28C boundary. Densities have varied between these areas over time and given the large size of the Middle Bay North stratum, extrapolation of higher densities occurring in only one or two of these areas could overestimate the biomass available to the fishery. Therefore the stratum was partitioned into two sections, with the dividing line along the deeper area between Quaco Ledge and the area adjacent to SFA 28C (Fig. 3).

The shell height distributions in the Cape Spencer area has exhibited moderate and regular recruitment over time sufficient enough to maintain a stable abundance of commercial size scallops (Fig. 25). While recruitment has declined over the last two years, there appears to be a larger than average abundance of scallops in the 40 to 64 mm range that should recruit to the fishery in 2010 (Fig. 26).

Since 2005, the abundance of scallops smaller than commercial size have been increasing in the Middle Bay North stratum (Fig. 27). These year-classes are not large relative to the 1998 year-class in SPA 1A and 4, they were distributed over a large part of the Middle Bay North area (see for e.g., Smith et al. 2008). In 2008, the highest mean catch per tow of scallops with shell heights 40 to 64 mm in the series was observed but these scallops are concentrated in the areas close to the 28C and Middle Bay South boundary (Fig. 28).

Trends in SFA 28C were similar to those in Middle Bay North with recent relatively strong year-classes (Fig. 29). Again similar to Middle Bay North the 2008 mean catch per tow of scallops with shell heights between 40 to 64 mm was the highest in the series (Fig. 30).

The Advocate Harbour area has exhibited strong recruitment signals over the last three years with the largest mean catch per tow of scallops 40 to 64 mm occurring in 2008 (Figs 31 and 32). Abundances are much lower in the SFA 28D Outer area with little evidence of recent strong year classes (Figs. 33 and 34). Mean catch per tow for the three major size classes have been declining over the last two years. The two remaining areas of Spencer's Island and Scots Bay exhibit higher densities than in the Outer area but lower than in Advocate (Figs. 35–38).

Based upon survey data over the last four years, the proportion of the total SPA 1B biomass was calculated for each of the major quota subareas.

Year	28B	28C	28D
2005	0.74	0.12	0.13
2006	0.78	0.10	0.12
2007	0.70	0.17	0.13
2008	0.78	0.13	0.09
Mean	0.75	0.13	0.12

Population model

The delay-difference model was fit to the combined survey biomass estimate and catches from SPA 1B from 1997 to 2008. Survey biomass was calculated by converting numbers-at-shell height to weight-at-shell height using meat weight/shell height relationships. Meat weight/shell height data was available for each area for almost all years while meat weights and ages were available in 2006 and 2007 only from all of the areas in SPA 1B. Model diagnostics based on the posterior

predictive distributions indicate that the model fits the data quite well as all of the probabilities of drawing a more extreme observation from the marginal posterior distributions are close to 0.5 and do not exceed the 0.025 and 0.975 bounds for extreme values (Fig. 39). Comparison of biomass forecasts from the model over the past 3 years indicates a small tendency to overestimate population (Fig. 40) in 2007/2008.

Stock status and forecast

The commercial size biomass increased from 1997 to 2003 and then declined until after 2006 when stronger than average recruitment entered the fishery over the next two years (Fig. 41a). From 1997 to 2003, the increases appear to be mainly due to biomass growth as the exploitation rates were very close to the replacement line (Fig. 41b). Exploitation rates higher than 0.15 resulted in declines in 2004, 2005 and 2006 while in higher levels of recruitment offset the higher levels of exploitation in 2007 and 2008. The prediction for the interim TAC for 2009 is an exploitation rate below the replacement line with resultant increase in biomass from 2008 to 2009.

Natural mortality is higher in SPA 1B than in SPA 1A based on the clapper data from the surveys. As a result the replacement line in SPA 1B is steeper than for SPA 1A, indicating a lower compensation for fishing by growth alone in the former area as the average meat weight of the commercial size biomass increases.

Catches less than 290 t should result in increases in biomass (Table 6). As noted in the Survey section recruitment prospects appear to be improving for 2009/2010 and this year-class will be commercial size for the 2010/2011 fishery.

SPA 3: Brier, Lurcher and St. Mary's Bay

Industry recommended a closed area for the 2008 fishery to protect young scallops observed in the 2007 survey. The efficacy of the closed area was evaluated after the 2008 SPA 3 survey in June was completed and Science Branch advised Fisheries Management, The Full Bay Scallop Association and the Grand Manan Fishermen's Association in an email dated June 30 that the voluntary closure was no longer necessary as the anticipated benefits of the closed area had not been realized (see below for analysis details). However, given the pattern of fishing locations in 2008 (Fig. 42) relative to previous years, no fishing took place in the closed area in 2008.

The quota for this area was set at 50 t pending the analysis of the 2008 survey data. In July the industry requested an increase in quota and an increase to 70 t was made based upon the decision table from last year's stock assessment. A total of 80 t was landed by September 30, 2008. This is the second lowest landing in this fishery since the early 1990s — the lowest at 34 t in 2002 was due to fishing effort being directed to more lucrative fisheries in SFA 29 and SPA 1A and 4 (Fig. 43).

Commercial fishery

Year	Avg. 98–03	2004	2005	2005/ 2006	2006/ 2007	2007/ 2008	2008/ 2009
TAC (t)	211	300	300	200	200	70.0	50[2]
Landing (t)	185	153	208	186	108	80.20[1]	11[3]

[1] landings based on 2007/08 quota report dated 28 November 2008.

[2] interim TAC.

[3] landings based on 2008/09 quota report dated 26 November 2008.

Commercial catch rate in 2008 was close to the median over the time series while effort has been declining since 2006 (Fig. 44). Given that the fishery concentrated in the eastern nearshore areas of SPA 3, where meat weights tend to be larger for given shell height it is possible that had fishing occurred over the whole area, the 2008 catch rate would be lower than observed (Fig. 42). In addition, recall that meat weights-at-shell height in the survey had declined from 2007 to 2008 possibly resulting a further decreases in catch rate (Fig. 7). There were only 5 meat weight samples obtained from the fishery and there some evidence there of a decline in meat weights from 2007 (Table 7).

Survey

The 2007 stock assessment (Smith et al. 2008) reported higher than average numbers per tow of scallops in the 10 to 50 mm size range in the Brier/Lurcher area (Fig. 45) of scallop production area (SPA) 3. Estimates of scallops in this size range are usually interpreted as being more qualitative than quantitative because of the 38 mm liner used in the lined gear. In the past, signs of good recruitment in the SPA 3 survey have not always panned out into actual recruitment (e.g., estimates in 2000 and 2004). High catches of pre-recruits have generally been found in the deeper waters of the Lurcher portion of the survey area where growth rates tend to be lower than areas closer inshore and to the north in the Brier portion of the survey. These deeper areas may contain marginal scallop habitat and the pre-recruits may not survive in sufficient numbers to become higher than average recruiting year-classes.

The important difference with the catches of pre-recruits in the 2007 survey was that the high catches were found over a broader area and closer inshore than usual (Fig. 46, upper left panel). It was assumed that if this wide-spread and shallower distribution resulted in increased survival, then higher numbers per tow would be observed in the 2008 survey for scallops with shell heights between 50 and 70 mm. The Full Bay Scallop fleet proposed a voluntary closure of much of SPA 3 to protect these small scallops. The closed area is marked on Fig. 46.

An evaluation of the June 2008 survey data indicated that the large numbers of small scallops in 2007 did not translate to increased numbers of the next size class of scallops in 2008 (Fig. 46, lower right panel and Fig. 45). Few scallops were observed in the 50 to 70 mm size range similar to recent years when fewer scallops less than 50 mm were caught (Fig. 45). The numbers per tow of scallops less than 50 mm observed in the 2008 survey were higher than those observed in the 2001 to 2006 but these catches were less than those for 2007. In 2008, scallops in this size range were widely distributed over the area similar to those in 2007 (Fig. 46, upper right panel). However,

giving the apparent poor survival of the the scallops less than 50 mm observed in the 2007 survey, it is difficult to say whether or not the small scallops in this year's survey will fare any better.

The double sampling scheme used for the 2007 survey was applied again in 2008. A total of 37 survey stations were randomly selected from stations fished in the Brier/Lurcher part of the 2007 survey to be included in the 2008 survey. A further 95 stations were randomly selected over the whole Brier Lurcher area. There was a strong correlation between the numbers of recruits and commercial size scallops and the commercial size scallops in the repeated tows in 2007 and 2008, respectively ($r = 0.90$, p-value< 0.0001, Fig. 47). Comparison of double sampling estimates between the 2007 and 2008 surveys indicate significant decreases in recruit and pre-recruit numbers and commercial size and recruits weight per tow (Table 8).

The impact of the restricted fishing area on the survey was investigated by calculating mean numbers and mean weights for the repeated and new tows separately for those stations in and outside of the closure box (Fig. 46). Year-to-year comparisons between repeated tows probably more accurately reflect actual annual changes and these comparisons indicate that both numbers and weights per tow of commercial size scallops increased for stations within the box while they declined for stations outside of the closure box (Table 9).

The 2008 survey in St. Mary's Bay indicates a potentially strong year-class at shell heights between 20 and 45 mm (Fig. 49). As noted in earlier assessments, the lined gear uses a 38 mm liner and hence catches of scallops in the above size range are qualitative at best. A similar sign of strong recruitment in the 2005 survey did not pan out in higher abundances in the 2006 survey. Overall, the survey indices for commercial size and recruit size scallops appear to have been stable over the last four years (Fig. 50).

Population models

A delay-difference model was fit to the survey data. Survey biomass was calculated from converting numbers-at-shell height to weight-at-shell height using meat weight/shell height relationships. A constant growth model over time was assumed based on parameter estimates from 2006 and 2007 age and meat weight data. The model generally estimated larger recruitment indices than were observed in the data but the probability of getting larger indices from the posterior estimates did not exceed the 0.025 and 0.975 bounds (Fig. 51). Overall, the delay-difference model fit the data well; however, there has been a tendency to underestimate biomass (Fig. 52). The model predicts a continued decline of commercial size biomass from 2007 to 2008 similar to the survey trends.

Stock status and forecast

The commercial size biomass is forecast to decrease for the interim quota of 50 t (Fig. 53a). Catches as low as 35 t will also result in a decline (Table 10). Recruitment is expected to be low for at least the next two years.

Exploitation over the 1996 to 2008 period has been high in this fishery, generally exceeding 0.2 (Fig. 53b). There have only been four years (1997, 1998, 2002 and 2003) when the biomass has increased and all were due to incoming recruitment. In addition, there was an increase in the biomass due to growth from 2002 to 2003 when only 34 t were landed in the 2002 fishery. The Full Bay fleet had directed its attention to SFA 29 and other areas in the Bay in 2002.

SPA 4: Digby

Landings data in what is now SPA 4 are available from 1976 to 2006 (Fig. 54). The season extends from 1 October to 30 April. Total landings were 79 t in 2007/2008 against at TAC of 100 t. An interim TAC for 2008/2009 was set at 100 t based upon last year's assessment.

Commercial Fishery

Year	Avg. 99–03	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008[1]	2008/ 2009
TAC (t)	520	1000	550	150	100	100	100[2]
Landing (t)	468	944	534	133	42	79	46[3]

[1] landings based on 2007/08 quota report dated 28 November 2008.

[2] interim TAC.

[3] landings based on 2008/09 quota report dated 26 November 2008.

Catch rates and effort have been declining since 2002/03 after the above average 1998 year-class recruited to the fishery (Fig. 55). Currently both catch rate and effort are below their long-term median levels. For recent years previous to 2006/2007 fishing has taken place from October through to May but in the last two seasons, fishing has mainly concentrated in October and April/May probably due to the lower quotas. The availability of meat weight samples appears to reflect the more limited fishing in the last two years (Table 11). Average meat weights appear to be lower in April/May in 2008 than they have been in recent years. The changing seasonal pattern in the fishery along with the seasonal pattern in meat weights may have an impact on our interpretation of annual changes in catch rates with respect to changes in population biomass. It is possible that decline in catch rate may be greater than that experienced by the population given the lower levels of fishing in 2007 from November through January when meat weights are expected to increase.

Survey

Areas of high densities of scallops less than 65 mm shell height were identified in SPA 4 and 1A in the 2007 survey. The Full Bay fleet recommended a closed area to DFO encompassing the distribution of the small scallops in SPA 4 and the adjoining area in SPA 1 (8 to 16 mile area). This close area went into effect October 2, 2007 (Maritimes Region Close Time Variation Order, 2007-123, Fig. 56). While the fishery did avoid this closed area (Fig. 8), there was no evidence of similar high densities in the 2008 survey (Figs 5, 4 and 57).

Overall, the survey indices indicate that the population has been stable since 2006 with low levels of recruitment, pre-recruits and clappers (Fig. 58). Given the trends in the pre-recruit estimates, low levels of recruitment will probably continue for the next two years.

Population model

The delay-difference model was fit to the survey and catch data. Survey biomass was calculated from converting numbers-at-shell height to weight-at-shell height using meat weight/shell height

relationships. As noted previously, the model generally tends toward smaller estimates of the number of clappers than was observed during the mass mortality event in 1989/1990 (Fig. 59). Overall, the model also tends toward higher recruitment estimates than were observed most years. However, for both the clapper and recruitment estimates, the posterior probabilities were within the 95 percent bounds and, therefore, consistent with the model. Similar to the performance of the model in the other areas, there is a tendency to overestimate biomass to a small degree in recent years (Fig. 60). The prediction for 2009 assumes a catch of 100 t in 2008/2009 and is also dependent upon the average meat weight-at-shell height being similar to that observed in 2008.

Stock status and forecast

Population biomass has been stable since 2005/2006 (Fig. 61a) and landings have been at their lowest in years. Recruitment is in the range of previous levels excluding the peak years of 1987/1988 and 2001. The exploitation rates for most years for which biomass had increased after the fishery were less than 0.16 and close to the replacement line. Increases in biomass in 1988 and 2002 were both due to the two strongest year-classes in the series. The high natural mortality experienced by the scallops in 1989 and 1990 resulted in declining populations despite the high levels of recruitment in 1988/1989. The interim TAC of 100 t for 2008/2009 should result in little change in the population biomass of commercial size scallops (Table 12).

SPA 5: Annapolis Basin

The fishery in the Annapolis Basin (SPA 5) is only open to the Full Bay fleet and has been quite small with a season running from 1 January to 31 March. In recent years, landings have varied between 2 and 20 t (Fig. 62).

Increased landings in 2003 and 2004 were due to strong recruitment of the 1999 and 2000 year-classes. Landings in 2008 were 7 t against a TAC of 10 t.

Commercial Fishery

Year	Avg. 99–03	2004	2005	2006	2007	2008
TAC (t)	11.4	25	10	15	10	10
Landing (t)	10.3	20	13	6	4	7

Commercial catch rate and effort are close to their respective long-term median levels (Fig. 63). Only one meat weight sample was obtained in 2008. Note that the survey indicates an increase in meat weight-at-shell height for SPA 5 (Fig. 7).

Survey

Shell height frequencies indicate that the 2007 year-class may be the strongest seen since the 1999 and 2000 year-classes (Fig. 64). Currently, the mean catch per tow for commercial size scallops is below the long-term median and close to the lowest seen in this series (Fig. 65).

Stock status and forecast

A population model has yet to be developed for this SPA. Based on the survey, the abundance of commercial size scallops has declined and is currently close to the lowest seen in the series. Good recruitment prospects may improve the stock status in 2010. The TAC for 2008 should not exceed the average catch of 9 t over the period 1997 to 2008 excluding the high catch in 2004.

SPA 6: Grand Manan and Southwest New Brunswick

Commercial Fishery

A total of 68 t was landed against a quota of 140 t in SPA 6 in 2008. Landings by area for 2008 for the Full Bay Fleet were 1.7, 1.9, 2.7, 1.1 t for SPA 6 A, B, C and D (Duck Island Sound; Fig. 66), respectively, against a TAC of 21 t (Table 14). This fleet has not caught its quota for the last 6 years as it has directed its effort to the other areas in the Bay (Figs 67 and 68).

The 2008 quota for the Mid Bay fleet was 105 t. Mid Bay landings for 2008 by area were 15.8 t, 10.8 t, 27.6 t and 6.3 t for SPA 6A, B, C and D, respectively (Table 14, Fig. 69).

Year	Avg. 98–03	2004	2005	2006	2007	2008
TAC (t)	163	195	195	100	140	140
FB: Landing (t)	19	8	5	4	5	7.4
MB: Landing (t)	114	74	81	87	64	61[1]

[1] landings to 28 November 2008.

Both catch and catch rates for both fleets have been relatively stable over the last four years (Fig. 70). Meat weight samples indicate that the commercial size portion of the population continues to get older on the average implying low recruitment over the last few years (Table 15).

Survey

As in 2006 and 2007, a repeated or double sampling survey design was used to deal with the patchiness of the distribution of scallops in SPA 6. Similar to 2007 this survey design was used in all subareas with 106 survey stations chosen randomly and 34 stations randomly chosen from locations surveyed in 2007. The survey was conducted in July using the F/V Royal Fundy. As was the case in 2007, sampling in SPA 6C did not extend along the New Brunswick shore to Mace's Bay (Fig. 71). The total number of tows was less than last year (140 vs. 169) because representatives for the Grand Manan fishery decided not to support funding additional survey stations in 2008.

Pre-recruits (40 to 64 mm) were more widely distributed in 2008 compared to 2007 with high concentrations in Passamaquoddy Bay and around the Wolves (Fig. 71, top row). Two exploratory tows in the Wolves area had in excess of 23,000 scallops mainly in the 20 to 55 mm shell height size range. In the 2007 survey the main concentration of recruits (65–79 mm) were in the Campobello Island area (6A); however, this year pre-recruit scallops seen in the Duck Island Sound area in 2007 appear as recruits in the 2008 survey (Fig. 71, middle row). Mean catch per tow for commercial

size scallops declined in the Duck Island Sound area in 2008, but the higher abundance of recruits in the survey should result in an increase in commercial size scallops for 2009 in this area.

Shell height frequency for each of subareas 6A, 6B and 6C indicate small increases in scallops less than 80 mm in shell height in 2008 relative to the last four or more years (Figs 72–74).

The repeated double sampling method was described in detail in Smith et al. (2007). A total of 9, 12 and 9 stations from the 2007 survey in SPA 6A, 6B and 6C, respectively were retained for the 2008 survey. Additional random stations were chosen to estimate the variance of the mean (6A: 36, 6B: 50 and 6C: 26). Correlation coefficients were calculated between catches of commercial size scallops ($\geq$80 mm shell height) in the two years as well as between numbers per tow of commercial size and recruits in 2007 with commercial size scallops in 2008 for each of the areas (Fig. 75 and Fig. 76). The correlations for 6A were the highest and most significant.

The differences between the means for 2007 and 2008 for each of the three areas were evaluated in Table 16. None of the means were significantly different between the two years, implying no changes in the survey estimates between the years.

Annual trends for commercial size scallops and recruits are presented for each sub-area in Figures 77 to 79. For each annual estimate of commercial size scallops, except for 2007 and 2008, 95 percent confidence intervals were calculated using the bootstrap method and empirical (percentile) limits. Confidence limits have not been defined for the repeated sample design estimates as of yet and the limits for 2007 and 2008 are simply twice the standard error of the combined mean. Comparison across confidence intervals suggests that there has been little change in mean numbers per tow of commercial size scallops in 6A, 6B or 6C.

Stock status and forecast

Evidence from the Mid Bay commercial catch rates and the surveys suggest that the abundance of commercial size scallops in 2008 is similar to that in 2007 in SPA 6A and 6B and 6C. Recent levels of catch do not appear to result in a decrease in the population abundance of scallops in the SPA 6 area as a whole.

Summary

As noted earlier, the approach to estimating and evaluating exploitation for SPA 1A, 1B, 3 and 4 has changed from previous years. Essentially the biomass estimates used to determine these exploitation rates are higher than those used previously because increases in growth and recruitment over the fishing season are now accounted for. One immediate result of this change is that the previously used reference exploitation level of 0.2 now appears to be too high to ensure at least no change in biomass between this year and the next. This does not imply a real change in our ideas about productivity, it only represents a change in scale. In addition, we do not recommend setting a single constant reference level for exploitation. Our analysis now suggests that the exploitation reference level should be evaluated in terms of the current average meat weight of the commercial size portion of the population and the growth potential of the scallops in the management area. While recruitment can provide additional productivity to the stock, these younger scallops are still in their prime growing years and will provide increased yield if allowed to grow for at least the next one to two years.

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Table 1. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 1A for the 2005/2006, 2006/2007, and 2007/2008 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
2005/2006 Season									
November	98	21.0	9.7	36.7	23.8	2	0.0	0.0	0.0
February	214	20.2	7.5	44.0	25.7	4	0.4	0.0	1.8
March	955	18.4	8.6	41.1	27.4	17	0.0	0.0	0.0
April	1093	21.5	5.4	45.0	24.5	22	1.4	0.0	17.8
May	1932	19.2	5.1	42.4	27.2	35	1.1	0.0	10.4
July	195	16.1	7.3	27.9	31.9	3	2.1	0.0	6.2
August	403	15.5	4.6	29.3	33.3	6	3.4	0.0	12.0
September	66	16.2	8.0	24.8	30.9	1	0.0	0.0	0.0
2006/2007 Season									
October	89	22.5	9.8	37.1	22.5	2	0.0	0.0	0.0
November	181	22.5	8.9	39.2	22.3	4	0.0	0.0	0.0
April	196	21.7	8.5	44.1	23.7	4	0.0	0.0	0.0
May	2002	21.6	1.6	51.9	23.8	41	0.7	0.0	6.9
June	241	21.5	10.6	35.5	23.3	5	0.0	0.0	0.0
August	288	18.0	7.5	36.4	28.0	5	0.3	0.0	1.7
2007/2008 Season									
October	119	26.5	11.3	46.1	19.6	3	0.0	0.0	0.0
April	504	23.5	8.7	52.2	22.3	11	0.0	0.0	0.0
May	925	23.0	5.0	58.8	22.6	20	0.1	0.0	2.0

Table 2. Decision table to evaluate catch levels in SPA 1A for 2008/2009 in terms of expected changes in biomass (percent). Posterior median exploitation rate given in column labelled e. Potential catches in 2009/2010 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.2.

2008/2009			$\Pr(e_{2009/2010} \geq 0.2)$					
Catch (t)	e	% Change	0.1	0.2	0.3	0.4	0.5	0.6
196	0.13	4.90	163	189	211	234	260	294
222	0.15	3.21	158	185	206	229	255	289
243	0.16	1.81	154	181	202	225	251	285
265	0.18	0.35	150	176	198	221	247	281
291	0.19	−1.36	145	171	193	216	242	276
324	0.22	−3.53	139	165	187	209	236	270

Table 3. Statistics from meat weight samples of the Upper Bay fleet scallop vessels in Scallop Production Area 1B for the 2006 and 2007 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
					Upper Bay				
2006 Season									
January	208	14.6	9.3	23.1	34.2	3	0.0	0.0	0.0
February	132	15.3	10.6	21.2	32.6	2	0.0	0.0	0.0
March	130	16.5	12.1	23.7	30.2	2	0.0	0.0	0.0
September	179	17.0	12.0	24.9	29.3	3	0.0	0.0	0.0
2007 Season									
January	199	15.3	10.1	23.4	32.7	3	0.0	0.0	0.0
February	140	14.4	8.8	21.0	34.8	2	0.0	0.0	0.0
April	137	14.8	7.7	24.3	33.9	2	0.7	0.0	1.4
August	257	15.8	12.0	24.0	31.7	4	0.0	0.0	0.0
September	64	15.7	7.8	23.4	31.9	1	1.6	1.6	1.6
2008 Season									
January	261	15.9	8.7	32.1	32.3	4	0.0	0.0	0.0
February	205	14.8	9.6	24.0	33.7	3	0.0	0.0	0.0
March	68	14.9	11.3	22.0	33.5	1	0.0	0.0	0.0
April	69	14.7	11.0	21.0	34.0	1	0.0	0.0	0.0
July	67	15.0	11.2	22.0	33.3	1	0.0	0.0	0.0

Table 4. Statistics from meat weight samples of the Mid-Bay fleet scallop vessels in Scallop Production Area 1B for the 2006 and 2007 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
					Cape Spencer				
2006 Season									
February	237	19.2	4.9	36.2	26.9	4	1.0	0.0	4.0
March	359	15.7	5.3	39.6	32.3	5	4.1	0.0	8.6
August	679	12.0	4.5	28.1	43.0	7	16.5	0.0	35.9
September	146	16.9	5.9	28.7	31.1	2	1.1	0.0	2.3
2007 Season									
January	75	15.9	6.9	31.1	31.5	1	5.3	5.3	5.3
February	53	17.2	5.9	31.5	29.1	1	1.9	1.9	1.9
March	143	14.5	7.2	23.1	34.6	2	1.4	0.0	2.9
April	62	21.1	8.0	31.6	23.7	1	0.0	0.0	0.0
August	41	21.8	9.3	38.8	22.9	1	0.0	0.0	0.0
September	259	18.3	9.1	33.4	27.5	5	0.0	0.0	0.0
2008 Season									
January	44	25.2	10.6	50.6	19.9	1	0.0	0	0
February	120	16.9	9.8	26.7	29.7	2	0.0	0	0
					Middle Bay North				
2006 Season									
February	395	15.0	5.7	33.8	34.9	5	3.9	0.0	11.2
March	335	20.3	5.8	38.8	25.2	6	1.8	0.0	5.3
April	48	21.7	10.3	38.9	23.1	1	0.0	0.0	0.0
August	347	17.1	7.3	33.2	29.4	5	0.8	0.0	2.6
September	62	18.0	9.7	28.4	27.8	1	0.0	0.0	0.0
2007 Season									
January	58	16.0	8.9	23.9	31.3	1	0.0	0.0	0.0
February	56	16.6	6.5	29.3	30.2	1	5.4	5.4	5.4
March	155	14.5	5.0	27.8	34.7	2	3.0	0.0	6.1
April	73	14.5	5.4	27.7	34.4	1	5.5	5.5	5.5
2008 Season									
March	48	23.6	3.3	40.9	21.1	1	2.1	0	0
					Upper Bay				
2006 Season									
January	272	14.8	11.0	23.0	34.0	4	0.0	0.0	0.0
February	46	22.2	14.0	35.5	22.5	1	0.0	0.0	0.0

Table 5. Statistics from meat weight samples of the Full Bay fleet scallop vessels in Scallop Production Area 1B for the 2006 and 2007 fishing seasons. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

Month	N	Meat Weight (g)			Count	Number of	Percent < 8 g		
		Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
					Cape Spencer				
2005/2006 Season									
February	92	12.1	6.1	22.7	41.3	1	5.4	5.4	5.4
March	275	18.6	7.6	41.3	27.2	5	0.4	0.0	1.8
April	57	18.1	12.5	24.2	27.6	1	0.0	0.0	0.0
May	197	15.5	8.4	35.5	32.5	3	0.0	0.0	0.0
August	307	13.8	6.7	26.7	36.2	4	2.9	0.0	5.5
September	216	14.4	7.9	26.8	34.8	3	0.5	0.0	1.5
2006/2007 Season									
October	65	15.7	8.8	24.5	31.8	1	0.0	0.0	0.0
February	55	17.9	7.3	34.7	28.0	1	5.5	5.5	5.5
May	108	19.0	7.4	33.7	26.5	2	1.7	0.0	3.4
July	49	21.5	12.7	34.3	23.2	1	0.0	0.0	0.0
August	355	17.4	7.9	29.6	28.9	6	0.3	0.0	1.5
September	109	18.5	7.9	30.5	27.1	2	0.9	0.0	1.9
2007/2008 Season									
October	41	24.7	13.8	35.9	20.2	1	0.0	0.0	0.0
					Middle Bay North				
2005/2006 Season									
February	60	17.3	9.4	36.4	28.9	1	0.0	0.0	0.0
March	242	16.9	6.5	27.7	29.7	4	0.4	0.0	1.5
April	88	23.8	16.0	35.6	21.3	2	0.0	0.0	0.0
May	128	16.3	9.3	25.3	30.8	2	0.0	0.0	0.0
June	51	19.5	8.9	32.5	25.6	1	0.0	0.0	0.0
July	188	17.0	7.4	31.2	30.9	3	0.8	0.0	2.4
September	82	15.8	9.5	27.9	31.7	1	0.0	0.0	0.0
2006/2007 Season									
May	133	23.7	8.0	39.3	21.5	3	0.0	0.0	0.0
August	410	20.4	6.9	44.2	25.0	8	0.4	0.0	3.6
September	224	23.6	5.3	43.0	21.8	5	0.8	0.0	3.9
2007/2008 Season									
October	40	25.0	12.4	39.0	20.0	1	0.0	0.0	0.0
					Upper Bay				
2005/2006 Season									
April	105	19.6	10.9	34.4	25.6	2	0.0	0.0	0.0
2006/2007 Season									
January	232	13.5	4.8	25.0	37.1	3	5.1	0.0	11.5
February	55	17.9	7.3	34.7	28.0	1	5.5	5.5	5.5
May	286	22.0	7.4	39.3	23.2	6	0.6	0.0	3.4
July	49	21.5	12.7	34.3	23.2	1	0.0	0.0	0.0
August	1087	19.1	4.2	44.2	26.7	20	0.5	0.0	3.6
September	514	20.5	5.3	43.0	25.3	10	0.6	0.0	3.9

Table 5. Statistics from meat weight samples of the Full Bay fleet scallop vessels in Scallop Production Area 1B cont'd.

Month	N	Meat Weight (g)			Count per 500 g.	Number of Samples	Percent < 8 g		
		Mean	Min.	Max.			Mean	Min.	Max.
					Upper Bay				
2007/2008 Season									
October	159	25.5	11.6	42.9	19.8	4	0.0	0.0	0.0
April	450	21.1	7.9	41.8	24.0	9	0.2	0.0	2.0
May	559	18.5	8.0	40.6	27.4	10	0.0	0.0	0.0
August	37	27.2	14.6	46.5	18.4	1	0.0	0.0	0.0

Table 6. Decision table to evaluate catch levels in SPA 1B for 2008/2009 in terms of expected changes in biomass (percent). Posterior median exploitation rate given in column labelled e. Potential catches in 2009/2010 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.2.

2008/2009			$\Pr(e_{2009/2010} \geq 0.2)$					
Catch (t)	e	% Change	0.1	0.2	0.3	0.4	0.5	0.6
261	0.13	1.37	217	253	282	312	343	379
296	0.15	−0.28	211	246	276	305	337	373
325	0.16	−1.68	206	241	271	300	331	368
354	0.18	−3.06	201	236	265	295	326	363
385	0.19	−4.52	196	230	260	289	320	357
421	0.21	−6.23	189	224	254	283	314	351

Table 7. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 3 for the 2005 to 2007/2008 fishing seasons. All samples collected by an industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
				St. Marys Bay					
2005/2006 Season									
June	163	26.1	5.5	51.3	20.2	4	1.7	0.0	2.9
2006/2007 Season									
June	92	22.8	9.5	66.0	23.0	2	0.0	0.0	0.0
August	50	21.0	7.9	33.8	23.8	1	2.0	2.0	2.0
				Brier Island					
2005/2006 Season									
October	341	17.7	6.0	33.9	28.4	6	2.1	0.0	9.3
November	54	19.0	10.7	29.4	26.2	1	0.0	0.0	0.0
June	112	20.1	6.8	43.9	27.7	2	1.4	0.0	2.7
July	66	15.3	7.7	28.8	32.8	1	1.5	1.5	1.5
August	63	16.4	7.9	28.3	30.5	1	1.6	1.6	1.6
September	112	18.8	8.7	31.1	27.2	2	0.0	0.0	0.0
2006/2007 Season									
August	93	25.0	6.3	47.7	21.8	2	2.5	0.0	4.9
September	38	26.4	17.7	40.9	19.0	1	0.0	0.0	0.0
2007/2008 Season									
June	159	18.9	8.2	36.8	26.5	3	0.0	0.0	0.0
				Lurcher Shoal					
2005/2006 Season									
April	85	12.6	7.4	20.4	39.6	1	2.4	2.4	2.4
May	312	13.3	6.2	22.5	37.9	4	2.8	1.3	5.1
June	341	14.5	4.3	49.9	35.0	5	3.6	0.0	14.5
July	193	15.8	8.0	27.2	31.9	3	0.0	0.0	0.0
August	786	17.1	7.5	34.8	29.6	13	0.6	0.0	2.8
September	562	18.4	8.6	36.9	27.7	10	0.0	0.0	0.0
2006/2007 Season									
May	80	12.7	7.7	22.9	39.3	1	1.3	1.3	1.3
July	111	18.3	7.4	34.1	27.4	2	0.9	0.0	1.9
August	96	21.6	10.8	34.3	23.2	2	0.0	0.0	0.0
September	92	24.5	11.4	40.0	22.5	2	0.0	0.0	0.0
2007/2008 Season									
October	51	19.8	11.2	31.9	25.2	1	0.0	0.0	0.0
June	60	16.8	11.2	27.1	29.8	1	0.0	0.0	0.0

Table 8. Double sample estimates of the mean number or weight per tow, difference between mean number or weight per tow for 2007 and 2008 and standard error (SE) of the difference for SPA 3. Critical values for test-statistic assuming t-distribution with 30 degrees of freedom = ± 2.04.

	Mean/tow					
Estimate	2007	2008	Difference	SE(Diff)	Test-Statistic	p-level
Commercial size numbers	82.98	74.05	−8.93	9.42	−0.95	0.349
Commercial size weights	1.34	0.99	−0.34	0.11	−3.25	0.003
Commercial size clappers	4.07	3.17	−0.90	0.96	−0.94	0.355
Recruits numbers	3.84	2.62	−1.22	0.56	−2.18	0.037
Recruits weights	0.02	0.01	−0.01	0.002	−4.44	< 0.001
Pre-recruits numbers	249.76	143.44	−106.32	41.81	−2.54	0.016

Table 9. Mean numbers and weights per tow for survey stations in the Brier/Lurcher of Scallop Production Area 3 for the whole area, area within the closure box for small scallops and outside of the closure box. New and repeated tows refer to the double sampling survey design — see text.

	Tow	sample	Numbers/tow		Weight(kg)/tow	
Area	Type	size	2007	2008	2007	2008
Whole Area	New tows	94	73.74	68.72	1.12	0.91
	Repeated	31	123.86	121.16	1.91	1.52
In box	New tows	25	55.95	51.62	0.94	0.80
	Repeated	9	60.09	70.26	0.90	0.99
Out box	New tows	69	80.18	75.01	1.19	0.95
	Repeated	22	146.05	141.98	2.26	1.74

Table 10. Decision table to evaluate catch levels in SPA 3 for 2008/2009 in terms of expected changes in biomass (percent). Posterior median exploitation rate given in columns labelled e.

Catch (t)	e	% Change
35	0.05	−14.19
45	0.09	−16.34
54	0.12	−18.28
64	0.16	−20.44
76	0.20	−23.03
91	0.25	−26.26

Table 11. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 4 for the 2004/2005, 2005/2006, 2006/2007, and 2007/2008 fishing seasons. All samples collected by an industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
2004/2005 Season									
October	3892	19.1	6.8	47.1	27.1	70	0.1	0.0	1.7
November	215	24.5	10.0	49.3	21.0	5	0.0	0.0	0.0
December	75	27.2	10.0	49.3	18.4	2	0.0	0.0	0.0
January	275	23.0	9.7	46.2	22.1	6	0.0	0.0	0.0
February	449	22.5	8.2	49.4	22.8	10	0.0	0.0	0.0
March	752	21.4	5.6	50.1	24.2	16	0.2	0.0	2.1
April	1357	21.1	6.8	46.3	24.6	27	0.1	0.0	1.7
May	343	18.0	7.9	28.9	28.1	6	0.6	0.0	1.8
2005/2006 Season									
October	216	21.2	6.8	45.8	26.7	4	0.7	0.0	1.5
November	229	18.5	7.2	39.0	27.6	4	0.5	0.0	2.0
February	43	23.9	12.3	45.8	20.9	1	0.0	0.0	0.0
March	477	21.7	8.4	45.1	23.7	10	0.0	0.0	0.0
April	222	20.1	7.4	40.2	27.4	4	0.6	0.0	2.4
May	49	21.1	11.3	31.2	23.7	1	0.0	0.0	0.0
2006/2007 Season									
October	876	20.8	5.9	45.9	25.0	17	1.2	0.0	20.2
November	138	14.9	7.2	25.4	34.0	2	1.5	1.3	1.6
April	515	25.5	6.3	46.0	20.8	12	1.9	0.0	17.6
May	421	25.9	7.5	50.9	20.4	10	0.2	0.0	2.1
2007/2008 Season									
October	255	23.6	10.8	58.7	21.2	6	0.0	0.0	0.0
November									
December									
January	48	21.6	14.2	36.1	23.2	1	0.0	0.0	0.0
April	298	17.6	2.2	35.1	29.1	5	0.8	0.0	2.0
May	113	18.9	10.3	37.1	27.5	2	0.0	0.0	0.0

Table 12. Decision table to evaluate catch levels in SPA 4 for 2008/2009 in terms of expected changes in biomass (percent). Posterior median exploitation rate given in column labelled e. Potential catches in 2009/2010 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.2.

	2008/2009		$\Pr(e_{2009/2010} \geq 0.2)$					
Catch (t)	e	% Change	0.1	0.2	0.3	0.4	0.5	0.6
75	0.11	3.40	61	74	87	102	121	143
87	0.13	1.90	59	72	85	100	118	141
100	0.15	0.37	57	69	82	97	116	139
115	0.17	−1.42	54	67	80	95	113	136
133	0.20	−3.58	51	63	76	91	110	132
156	0.23	−6.27	46	59	72	87	105	128

Table 13. Statistics from meat weight samples of Full Bay fleet scallop vessels in Scallop Production Area 5 for the 2002, 2003 and 2005 fishing seasons. No samples were collected from the 2004, 2006 and 2007 fisheries. All samples collected by industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
2002 Season									
January	282	22.0	7.3	61.5	22.9	6	0.7	0.0	4.1
2003 Season									
January	80	26.2	9.9	84.8	19.2	2	0.0	0.0	0.0
February	49	21.2	10.4	51.2	23.6	1	0.0	0.0	0.0
2004 Season									
					No samples				
2005 Season									
January	662	22.6	7.3	61.1	22.6	14	0.13	0.0	1.75
2006 Season									
					No samples				
2007 Season									
					No samples				
2008 Season									
January	39	26.4	15.1	48.6	19	1	0.0	0.0	0.0

Table 14. Catch by fleet and subarea for Scallop Production Area 6. 2008 landings as of 28 November, 2008.

	Catch (meats, t)							
Subarea	2001	2002	2003	2004	2005	2006	2007	2008
Full Bay								
TAC	50	50	50	50	25	35	35	21
6A	3.9	2.3	16.3	1.1	0.3	0.9	2.3	1.7
6B	7.4	0.1	0.0	0.6	3.2	1.7	1.7	1.9
6C	5.1	5.0	4.6	3.7	0.2	0.3	0.1	2.7
6D		0.7	0.0	2.8	1.2	1.4	0.8	1.1
Total	16.3	8.2	20.9	8.1	4.9	4.4	4.9	7.4
Mid-Bay								
TAC	105	145	145	145	145	75	105	119
6A	25.9	16.0	10.2	13.1	38.0	25.2	22.2	15.8
6B	73.2	27.4	7.2	14.5	18.1	23.7	11.3	10.8
6C	46.5	59.9	43.5	23.9	16.7	19.8	23.8	27.6
6D		16.2	0.3	22.4	7.9	18.0	6.7	6.3
Total	145.6	119.5	61.2	74.0	80.7	86.7	64.0	60.6

Table 15. Statistics from meat weight samples of the Mid and Full Bay fleets scallop vessels in Scallop Production Area 6 for the 2007 and 2008 fishing seasons. All samples collected by an industry supported dockside monitoring program. Statistics on the percentage by number of meats in the sample that were less than 8 g are also given.

		Meat Weight (g)			Count	Number of	Percent < 8 g		
Month	N	Mean	Min.	Max.	per 500 g.	Samples	Mean	Min.	Max.
					Mid-Bay				
SPA 6A									
2007 Season									
January	50	19.9	11.7	28.4	25.1	1	0.0	0.0	0.0
February	40	23.5	10.9	42.4	21.3	1	0.0	0.0	0.0
August	59	16.9	7.9	24.7	29.6	1	1.7	1.7	1.7
2008 Season									
January	158	25.7	8.7	51.6	20.8	4	0.0	0	0
February	37	26.3	6.0	69.5	19.0	1	5.4	0	0
SPA 6B									
2007 Season									
January	239	19.9	5.7	44.6	25.4	5	1.1	0.0	5.6
February	237	22.1	5.5	44.0	24.7	5	2.4	0.0	12.0
March	73	13.7	6.4	22.4	36.6	1	9.6	9.6	9.6
2008 Season									
January	136	21.7	10.4	38.7	23.2	3	0	0	0
February	104	19.4	11.4	29.4	25.8	2	0	0	0
March	44	20.6	10.3	26.8	24.3	1	0	0	0
SPA 6C									
2007 Season									
January	340	19.5	4.2	63.7	26.9	7	5.7	0.0	12.1
February	577	19.6	4.1	62.0	26.9	11	3.6	0.0	10.8
March	166	18.1	5.2	49.6	27.7	3	4.3	0.0	11.1
2008 Season									
January	102	20.4	8.3	44.7	24.6	2	0.0	0	0
February	972	22.3	6.1	86.0	24.1	21	1.7	0	11
March	32	31.7	6.6	62.1	15.8	1	3.1	0	0
					Full Bay				
SPA 6B									
2006 Season									
March	70	13.7	6.0	25.1	36.6	1	4.3	4.3	4.3
2008 Season									
February	44	21.9	10.5	38.9	22.9	1	0	0	0

Table 16. Double sample estimates of the mean number per tow, difference between mean number per tow for 2007 and 2008 and standard error (SE) of the difference for SPA 6. Test statistic tested using a Student's t distribution.

Estimate	Mean/tow 2007	Mean/tow 2008	Difference	SE(Diff)	Test-Statistic (p-value)
Commercial size in 2007					
6A	63.23	73.36	10.13	23.37	0.43 ($p = 0.68$)
6B	75.44	66.07	−9.37	7.97	-1.17 ($p = 0.26$)
6C	12.87	12.77	−0.09	4.00	-0.02 ($p = 0.98$)
Commercial+recruits in 2007					
6A	60.29	73.48	13.19	23.41	0.56 ($p = 0.59$)
6B	75.88	64.43	−11.45	7.75	-1.47 ($p = 0.16$)
6C	13.05	11.74	−1.31	3.83	-0.34 ($p = 0.74$)

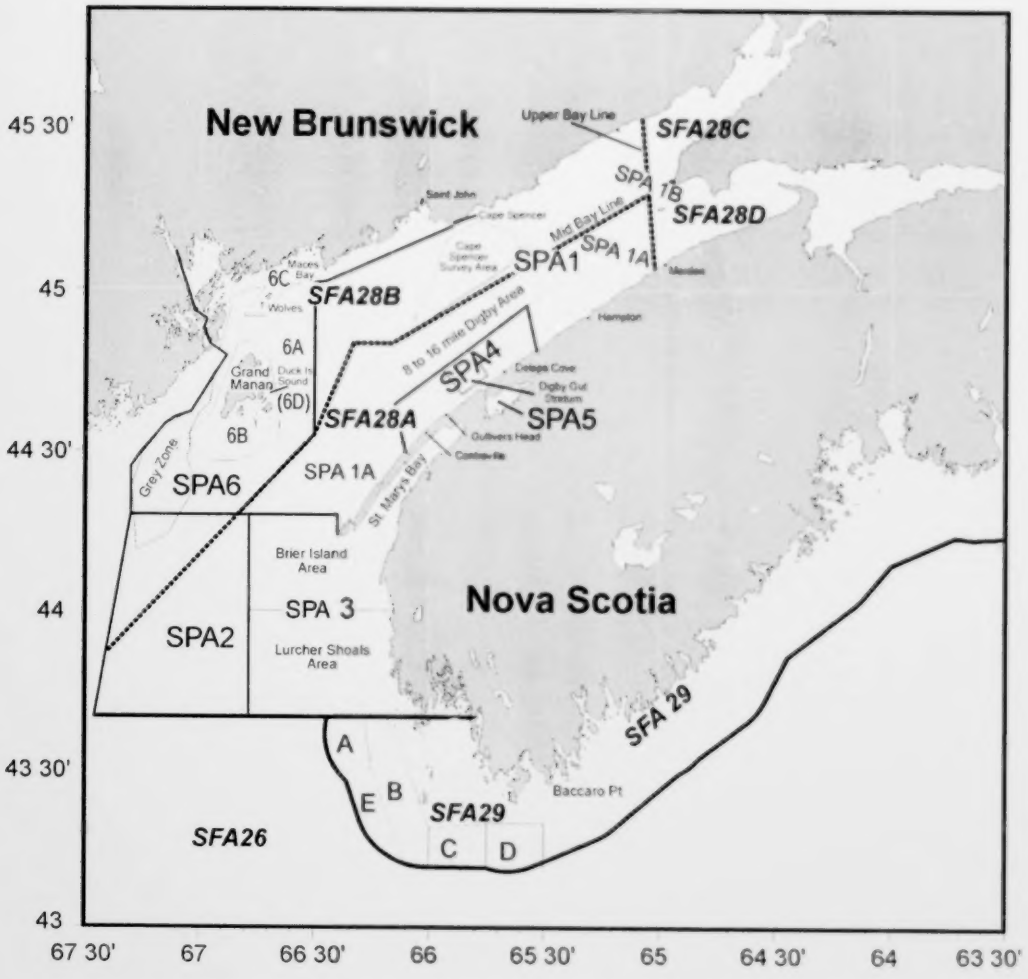

Fig. 1. Scallop Production Areas and Scallop Fishing Areas in the Bay of Fundy.

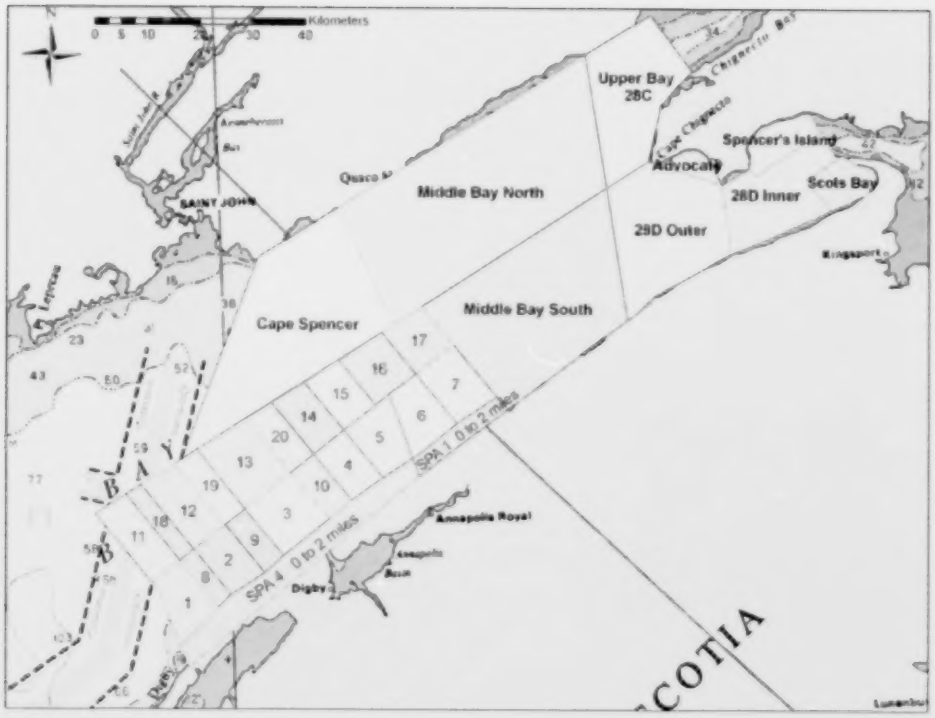

Fig. 2. Map of survey strata for the Bay of Fundy scallop survey.

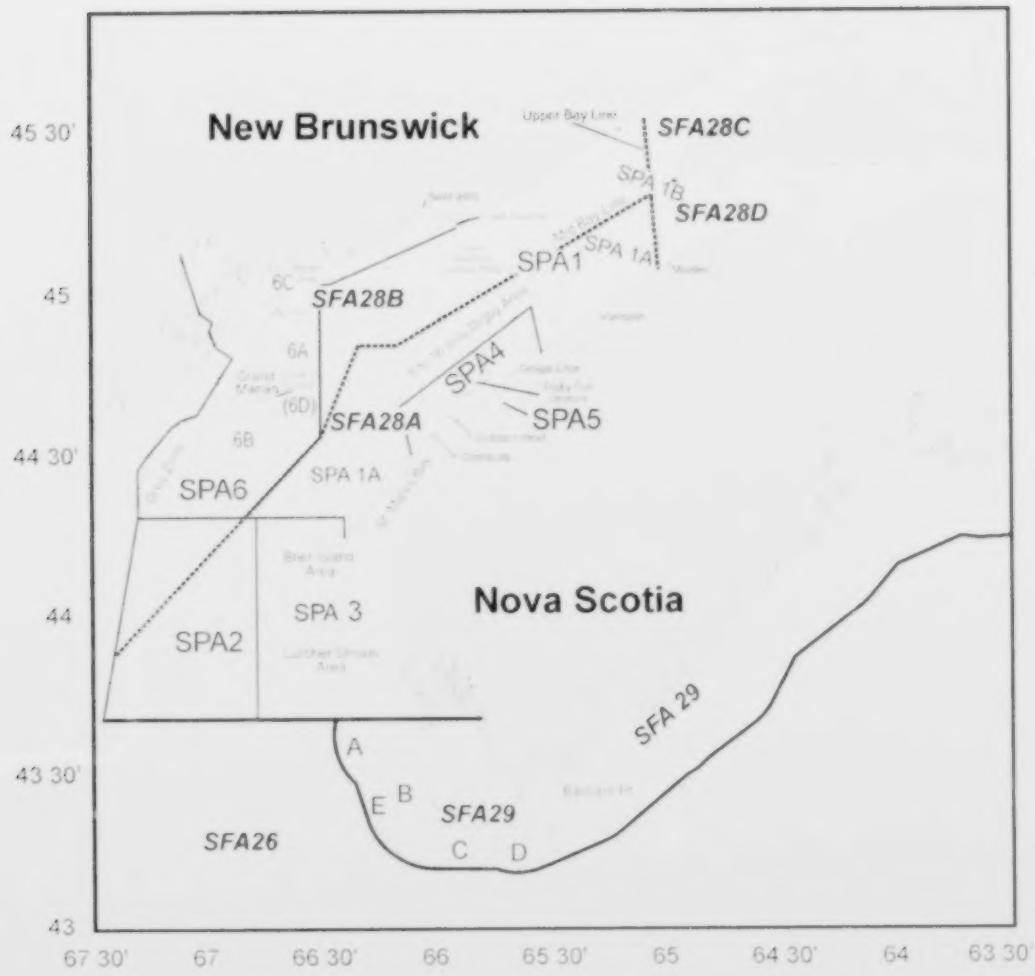

Fig. 1. Scallop Production Areas and Scallop Fishing Areas in the Bay of Fundy.

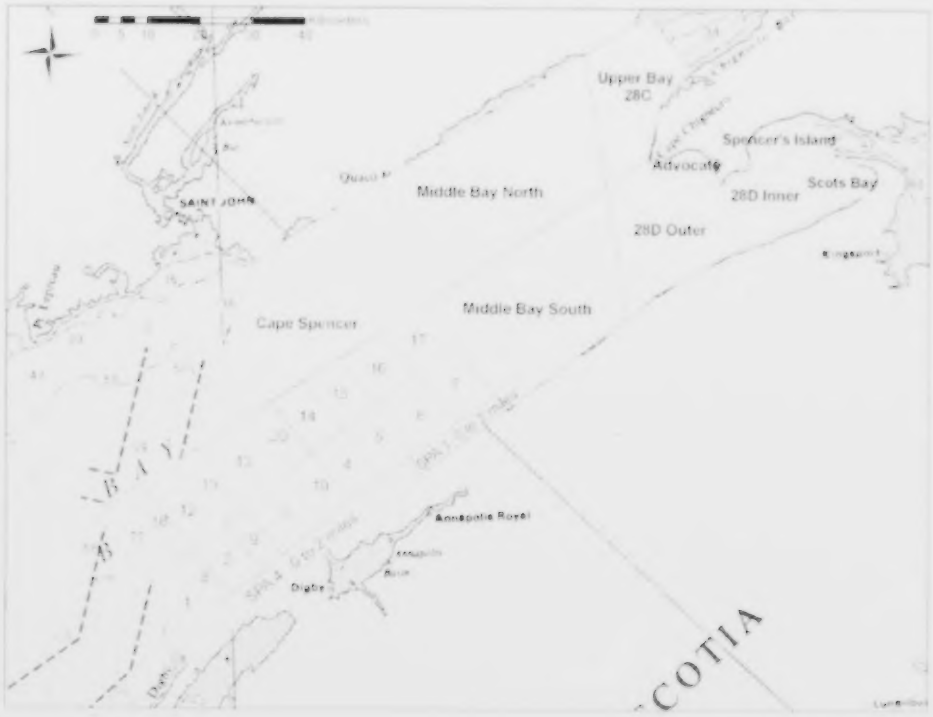

Fig. 2. Map of survey strata for the Bay of Fundy scallop survey.

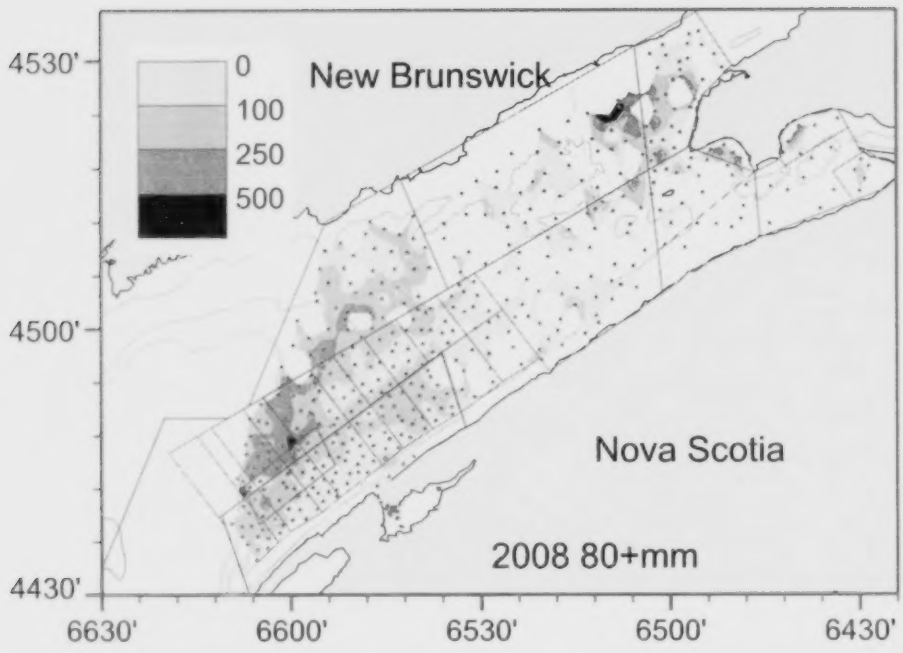

Fig. 3. Spatial distribution of catches from the 2008 survey of Scallop Production Areas 1 and 4 for commercial size (≥ 80 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

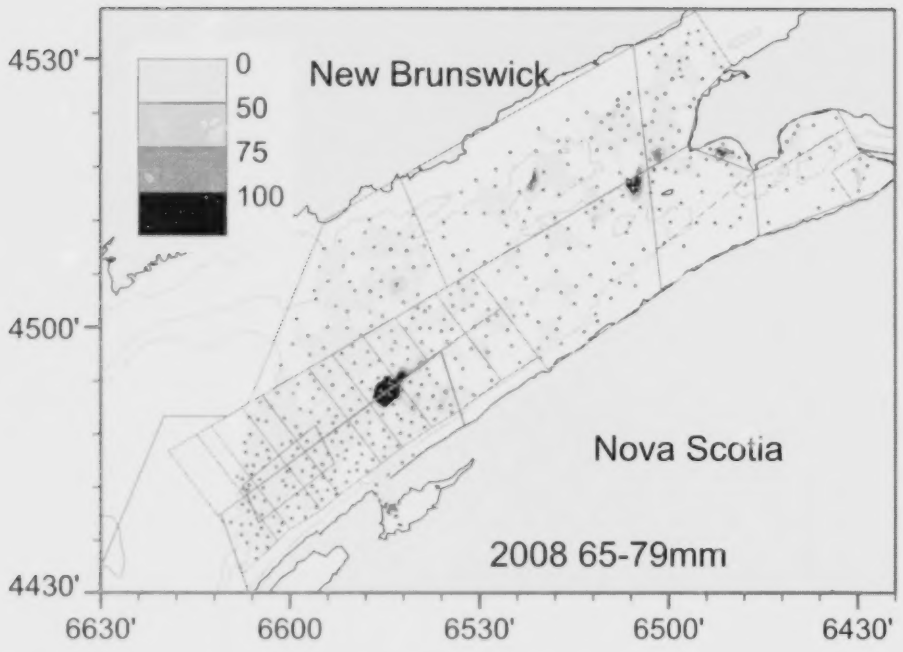

Fig. 4. Spatial distribution of catches from the 2008 survey of Scallop Production Areas 1 and 4 for recruit size (65 to 79 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

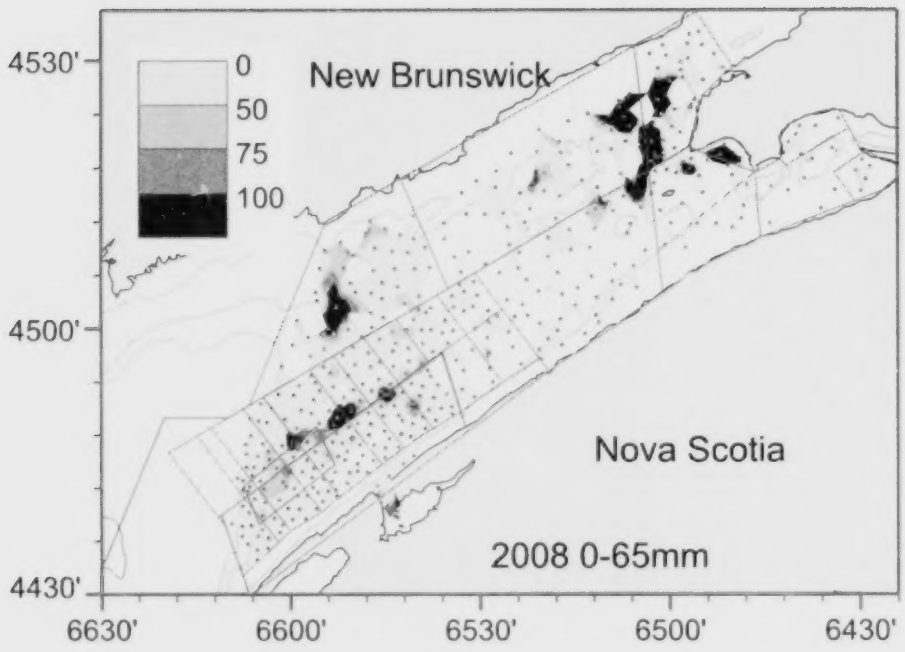

Fig. 5. Spatial distribution of catches from the 2008 survey of Scallop Production Areas 1 and 4 for pre-recruit size (< 65 mm shell height) scallops. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

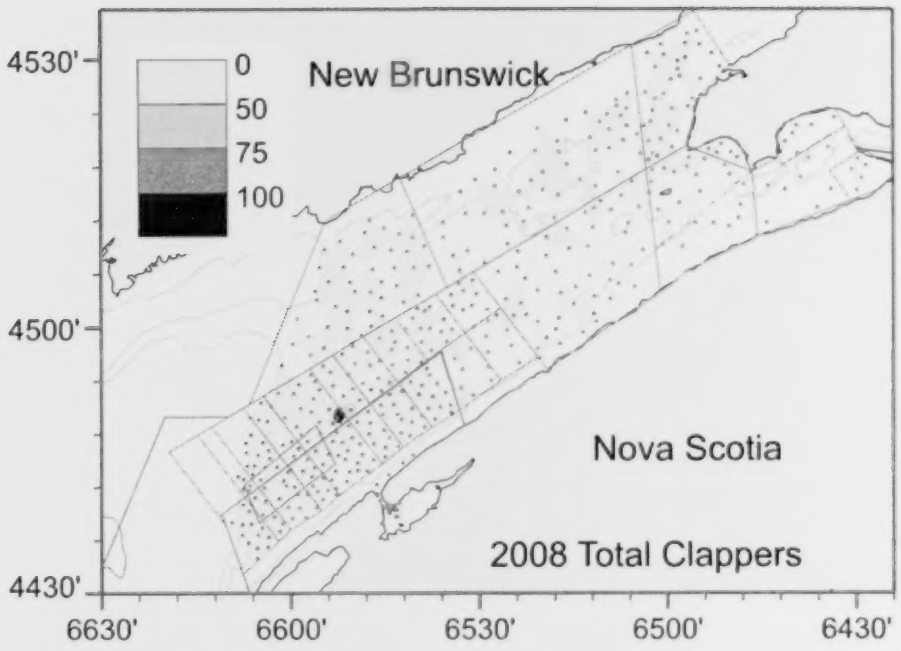

Fig. 6. Spatial distribution of catches from the 2008 survey of Scallop Production Areas 1 and 4 for all sizes of scallop clappers (paired empty shells). Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

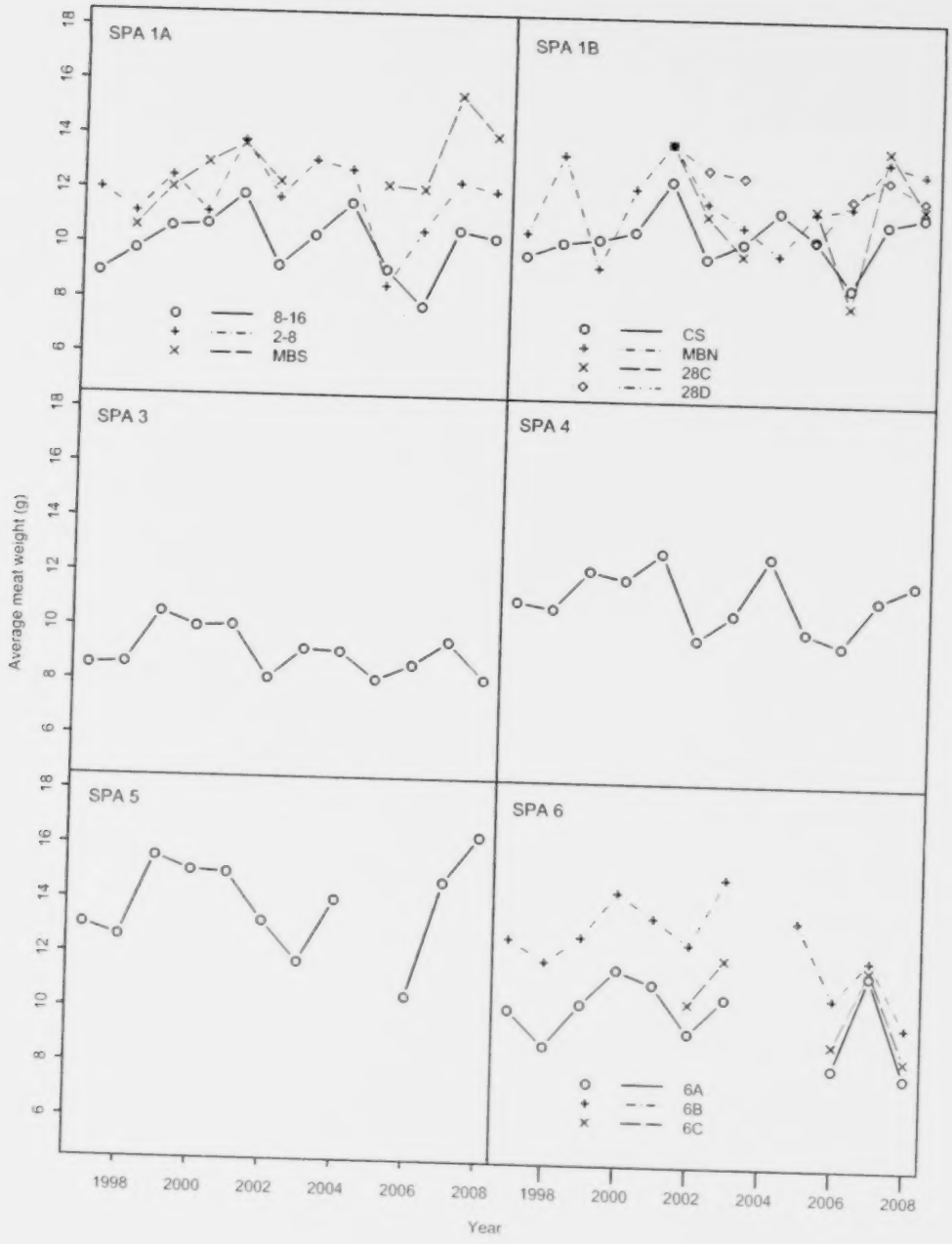

Fig. 7. Predicted meat weights (g) for scallops with 100 mm shell height at time of survey.

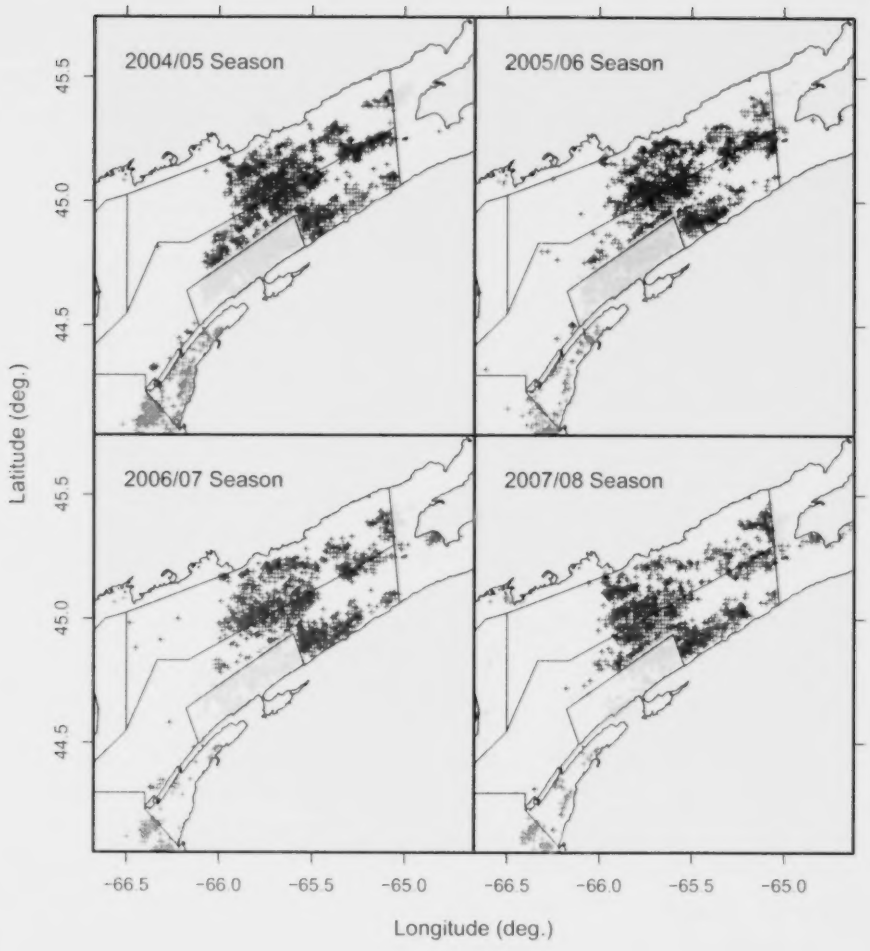

Fig. 8. Fishing locations based upon commercial fishing logs from the Full Bay Fleet in Scallop Production Areas 1A, 1B and 4.

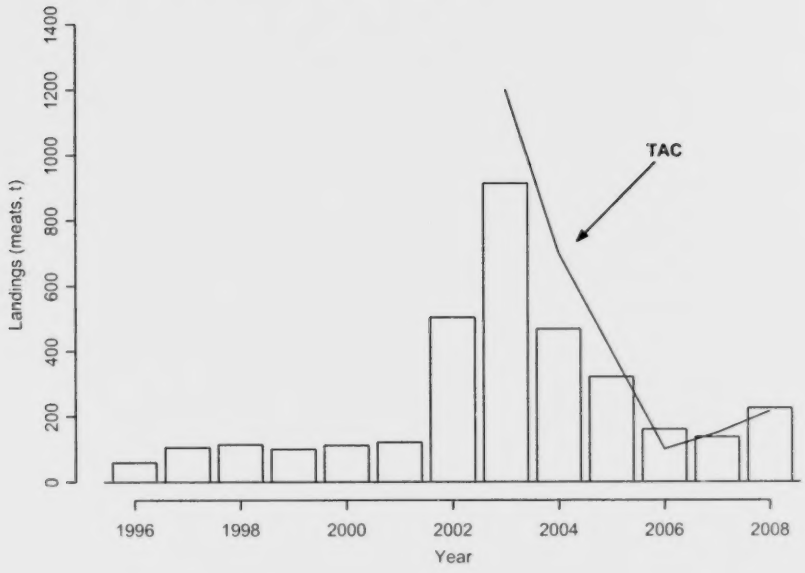

Fig. 9. Scallop landings (meats, t) in Scallop Production Area 1A by the Full Bay Fleet.

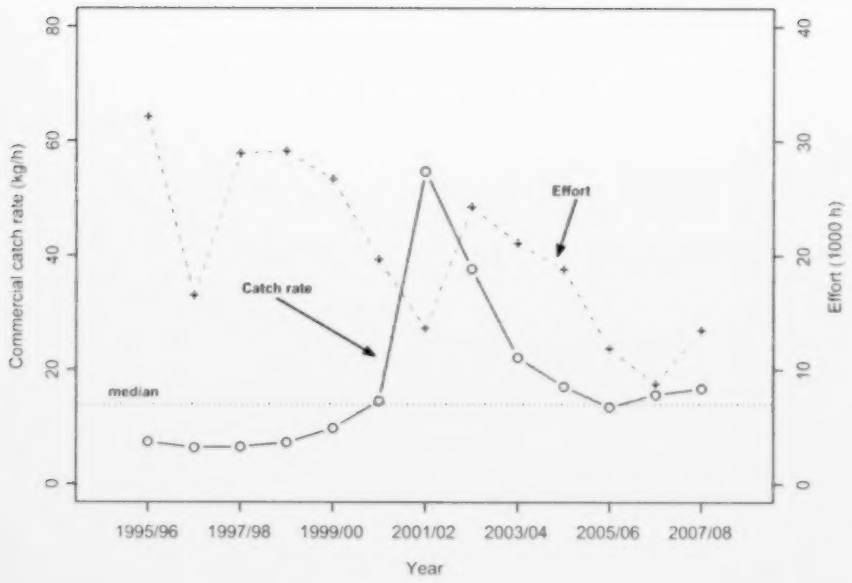

Fig. 10. Trends in a) scallop catch rate (kg/h) and b) effort (1000 h) from SPA 1A. Median catch rate over the 1995/1996 to 2006/2007 fishing season indicated.

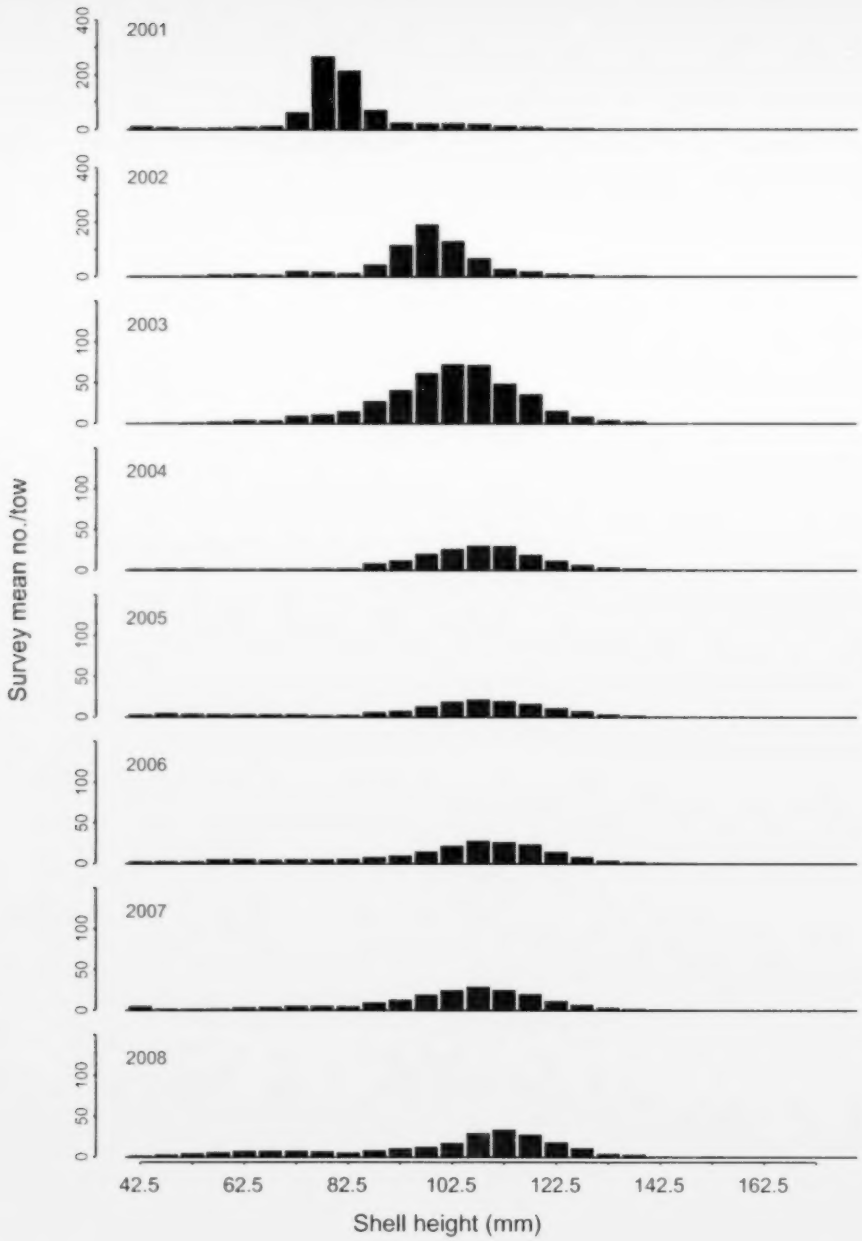

Fig. 11. Scallop shell height frequencies (mean number/tow) from the surveys of the 8–16 mile area of Scallop Production Area 1A. Note the change in scale on the y-axis between 2002 and 2003.

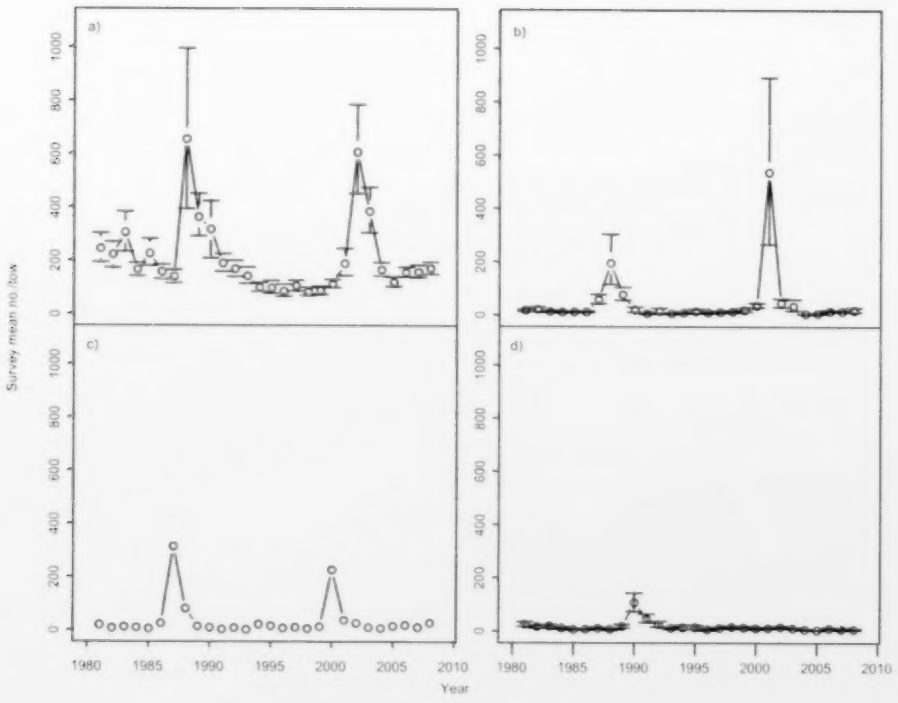

Fig. 12. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) for scallops in the 8–16 mile area of Scallop Production Area 1A. 95 percent bootstrap confidence intervals are included.

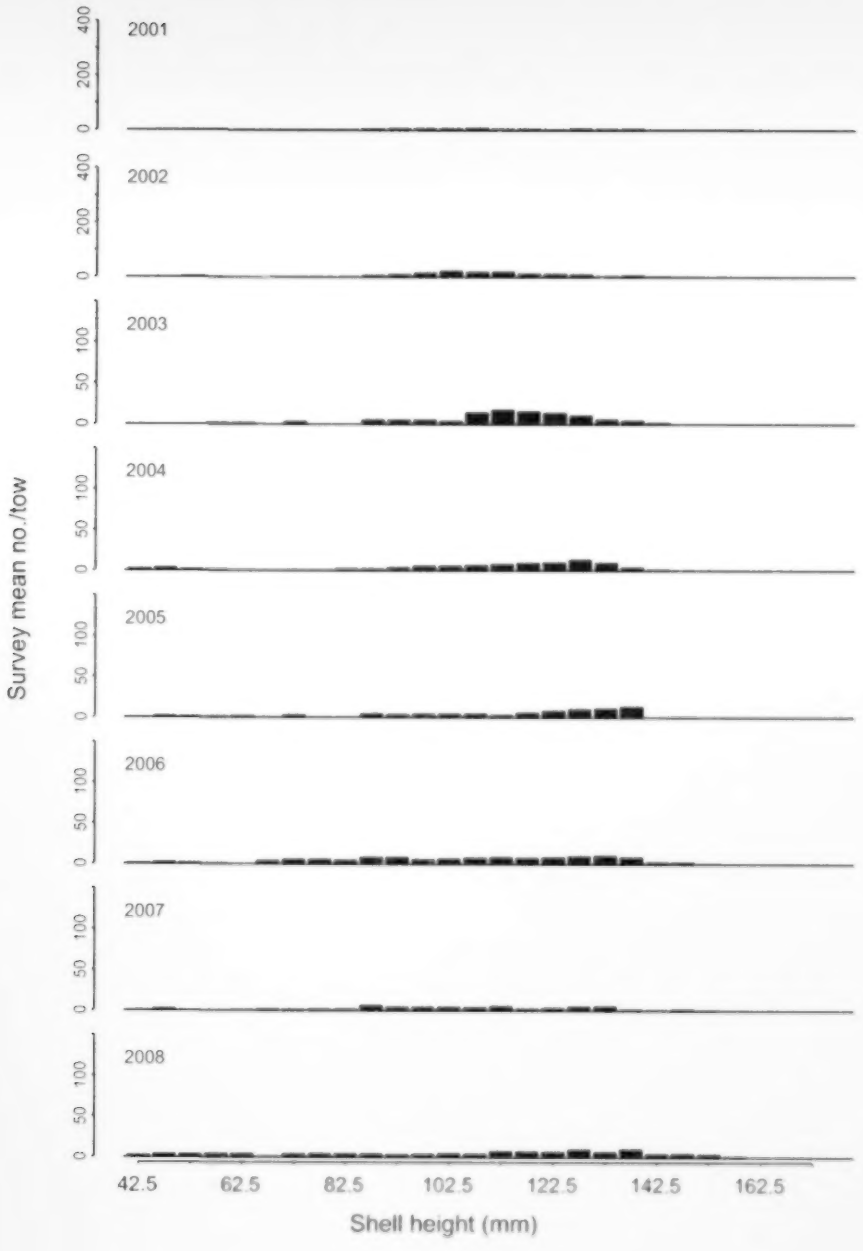

Fig. 13. Scallop shell height frequencies (mean number/tow) from the surveys of the 2–8 mile Youngs Cove and Hampton strata (Fig. 2: 2–8, 1A) of Scallop Production Area 1A. Note the change in scale on the y-axis between 2002 and 2003.

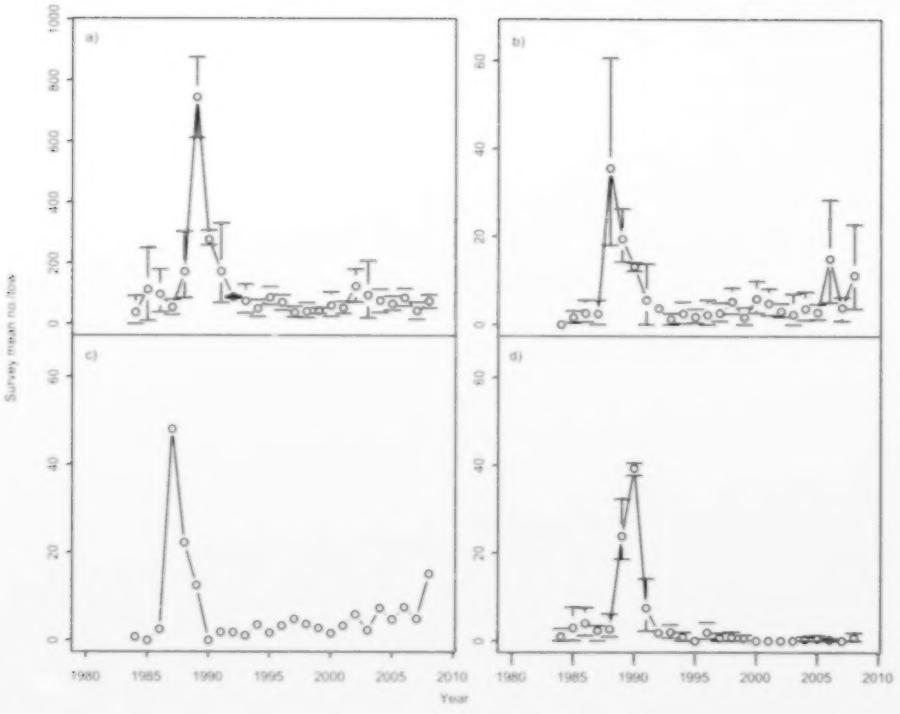

Fig. 14. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the 2–8 mile Youngs Cove and Hampton strata (Fig. 2: 2–8, 1A) of Scallop Production Area 1A. 95 percent bootstrap confidence intervals are included.

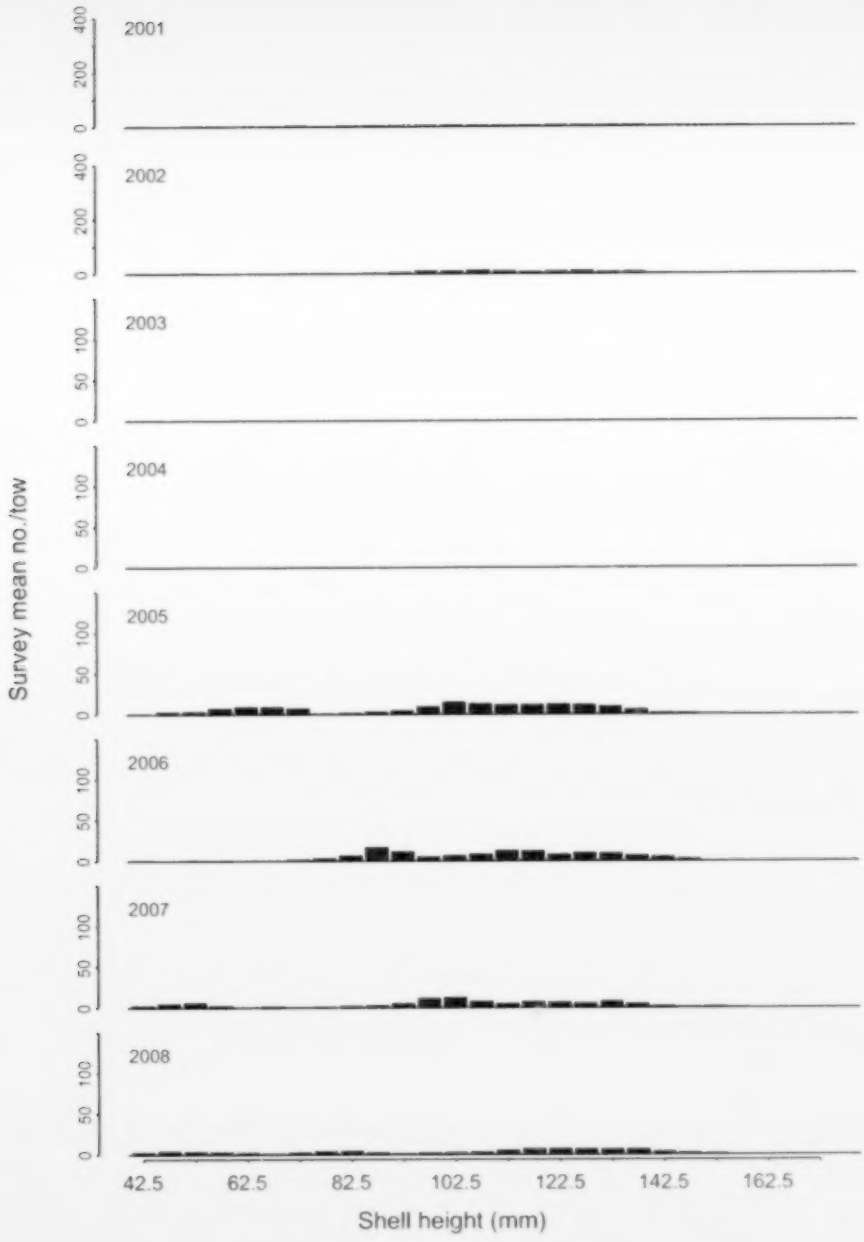

Fig. 15. Scallop shell height frequencies (mean number/tow) from the surveys of the Middle Bay South area of Scallop Production Area 1A. Note the change in scale on the y-axis between 2002 and 2003.

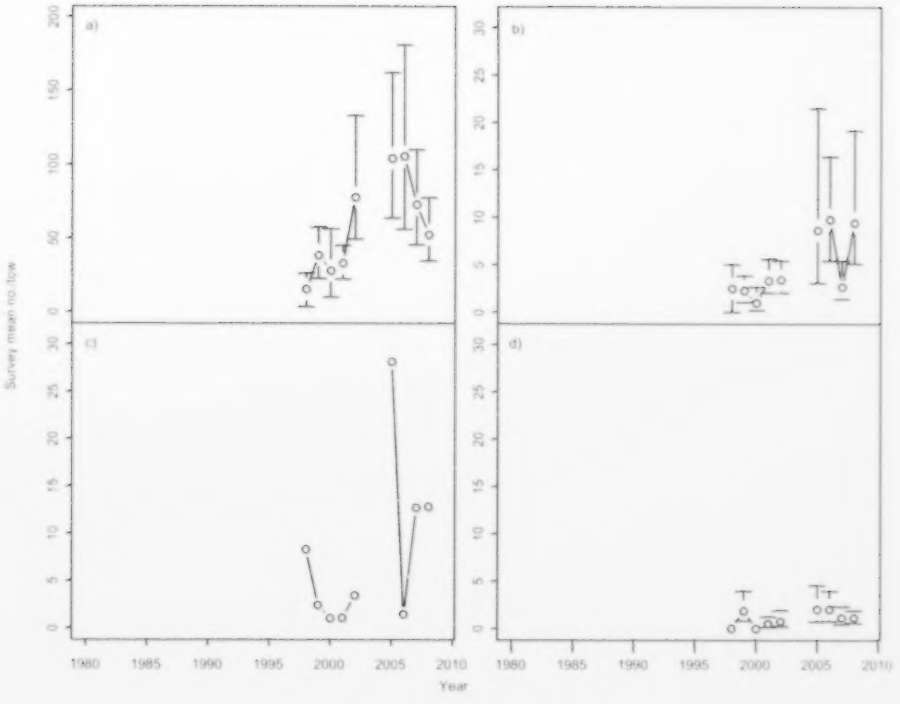

Fig. 16. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm); and d) clappers (≥ 80 mm) scallops in the Middle Bay South area of Scallop Production Area 1A. 95 percent bootstrap confidence intervals are included.

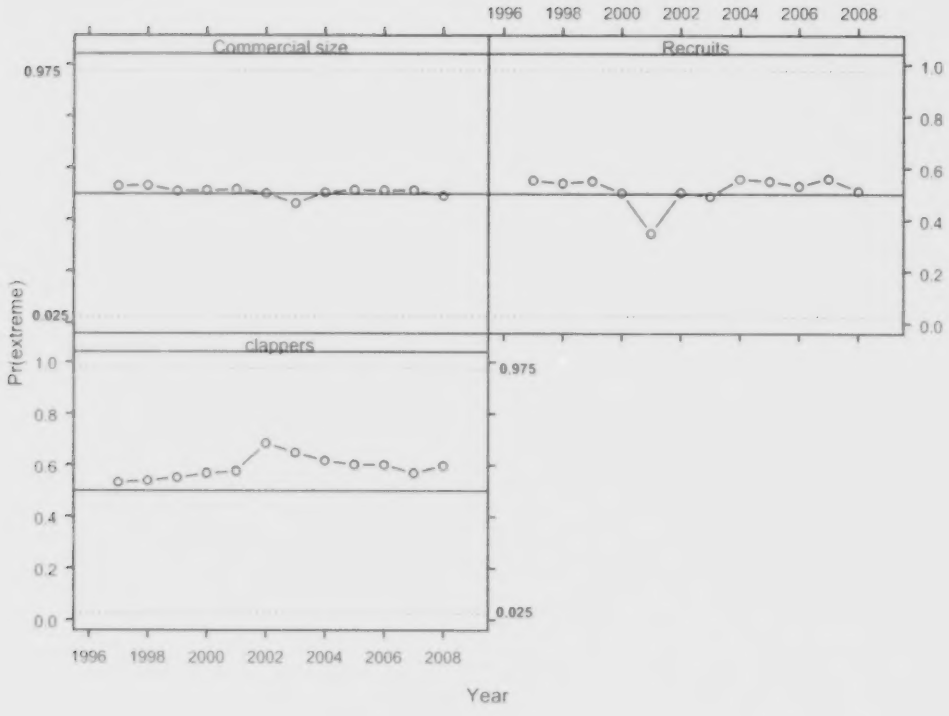

Fig. 17. Probabilities of getting larger observations than obtained for survey estimates of Biomass, recruits and clappers for the delay-difference model in SPA 1A. Dotted lines indicate probabilities of 0.025 and 0.975.

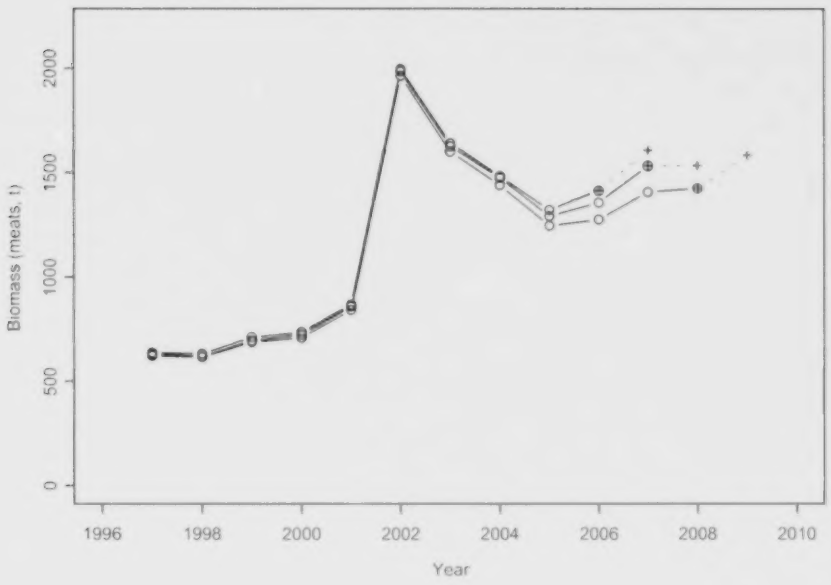

Fig. 18. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size scallops (≥ 80 mm shell height) in the current year in Scallop Production Area 1A. Predictions and current year estimates were produced from the delay-difference population model. Prediction for 2009 made assuming a 2008/2009 catch of 120 t.

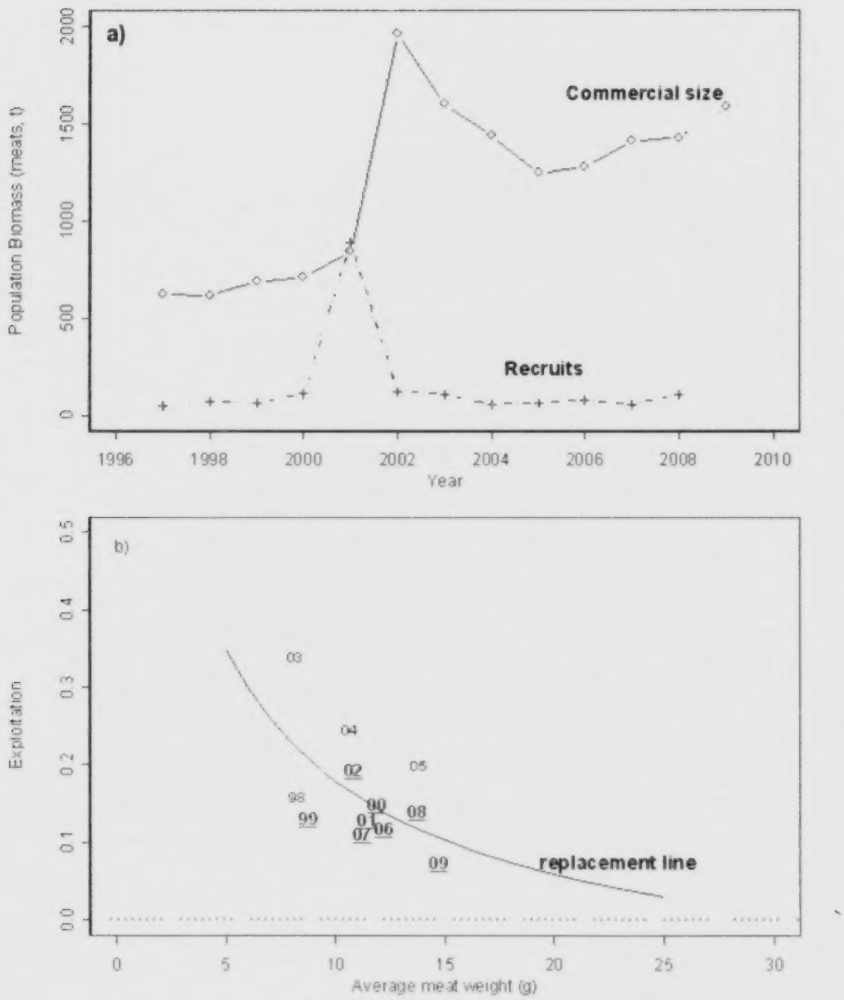

Fig. 19. a) Estimated population biomass for commercial and recruit size scallops in Scallop Production Area 1A. The prediction for 2009 was made assuming the interim TAC of 120 t for 2008/2009. b) Exploitation rate (Catch/Commercial size Biomass) versus average meat weight of the commercial size scallops. The replacement line refers to the increase in biomass due to growth discounted for natural mortality. Points are labelled by the end of fishing year (i.e., 09 for 2008/2009). Those years printed in larger underlined font (and coloured red) indicate that the population biomass increased after the fishery. Years in the smaller font (and coloured black) were those in which the biomass declined after the fishery. Refer to panel a) for the trends in biomass.

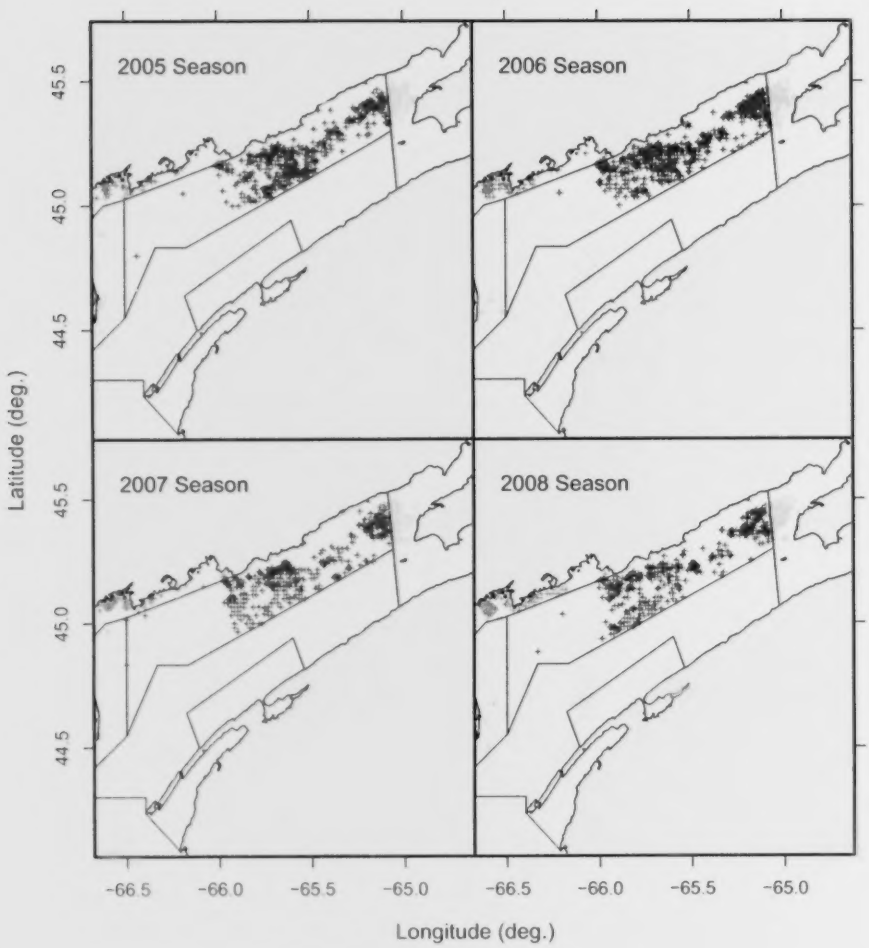

Fig. 20. Fishing locations based upon commercial fishing logs from the Mid-Bay Fleet in Scallop Production Area 1B.

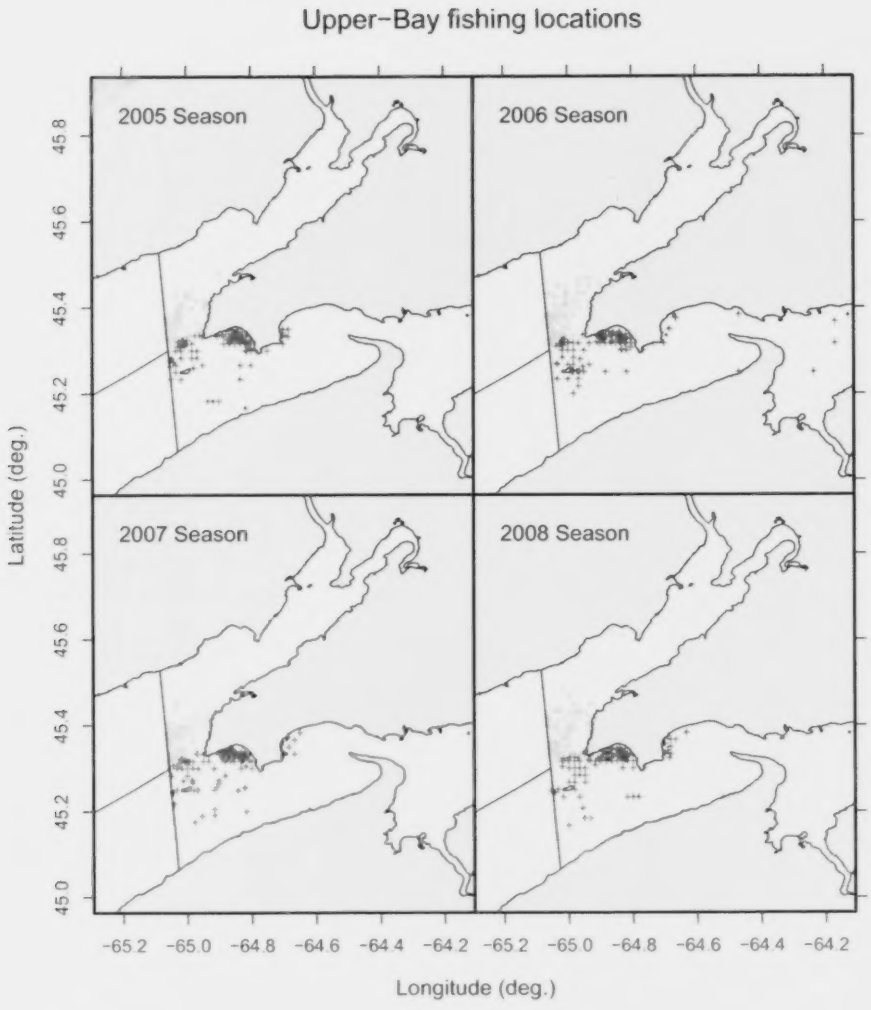

Fig. 21. Fishing locations based upon commercial fishing logs from the Upper Bay Fleet in Scallop Production Area 1B, Scallop Fishing Areas 28C and 28D.

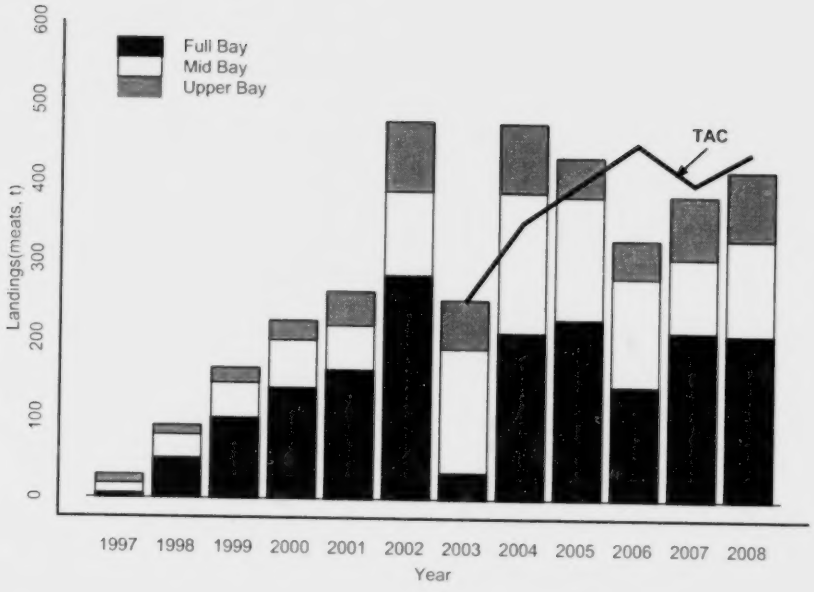

Fig. 22. Scallop landings (meats, t) in Scallop Production Area 1B by each fleet.

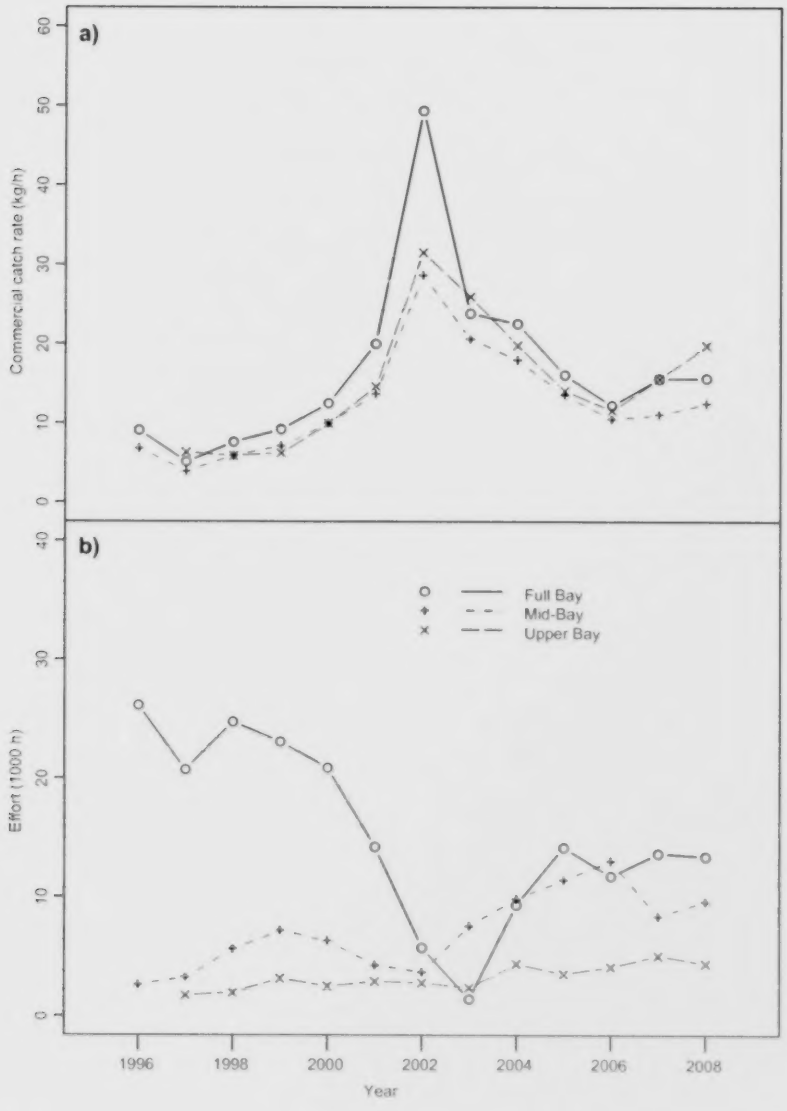

Fig. 23. a) Commercial catch rate (kg/h) and b) Effort for each fleet in Scallop Production Area 1B.

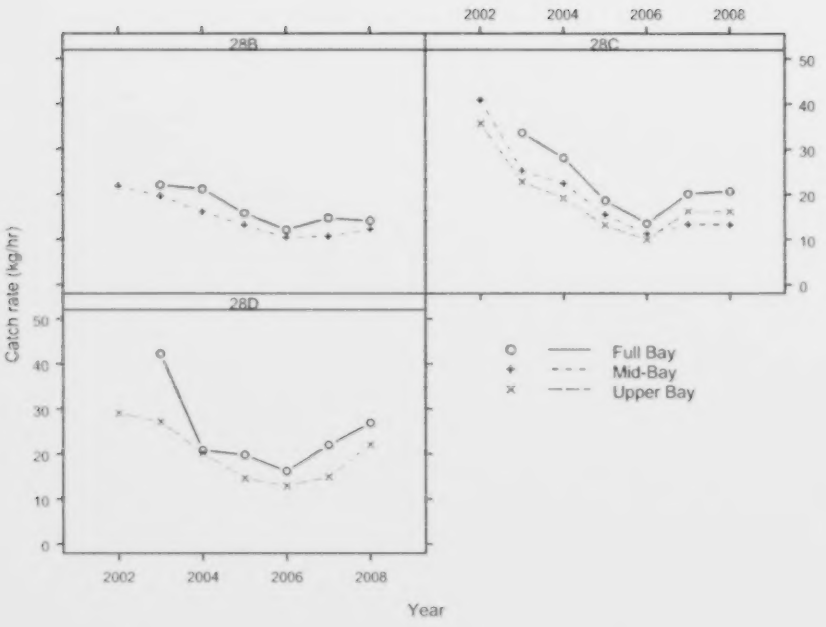

Fig. 24. Commercial catch rate (kg/h) for each fleet and subarea in Scallop Production Area 1B.

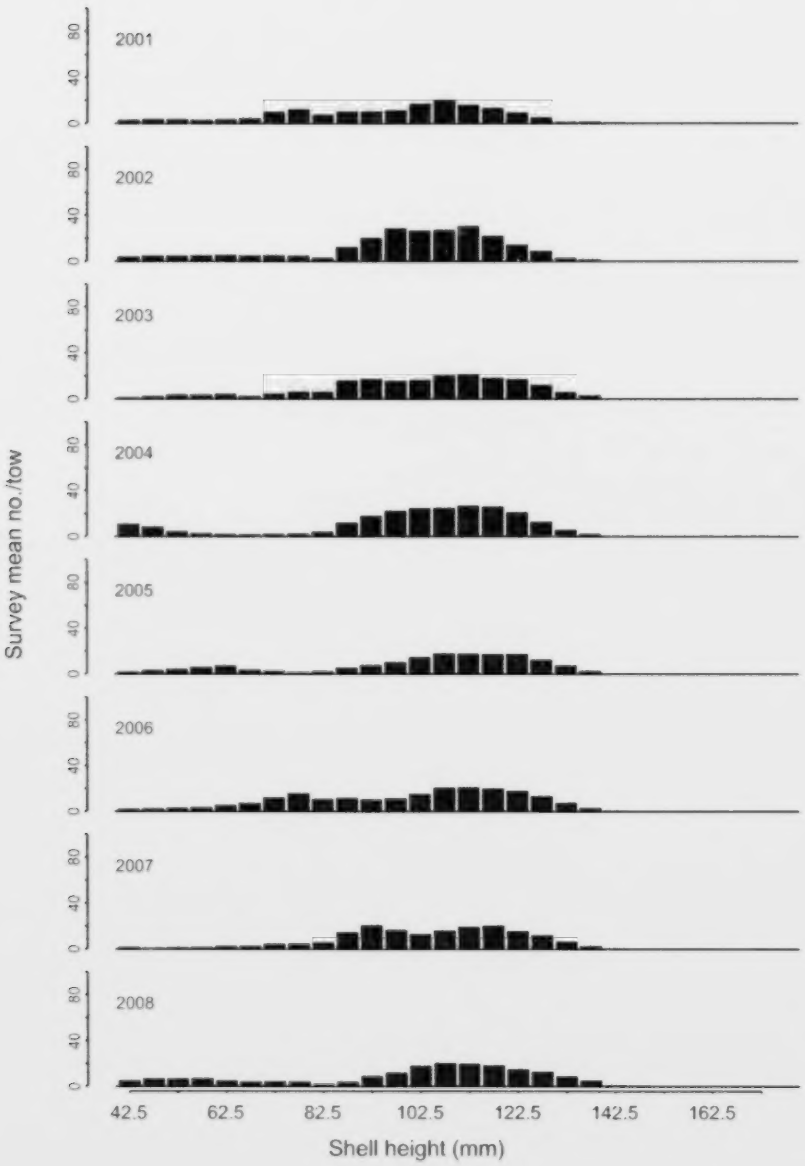

Fig. 25. Scallop shell height frequencies (mean number/tow) from the surveys of the Cape Spencer area of Scallop Production Area 1B.

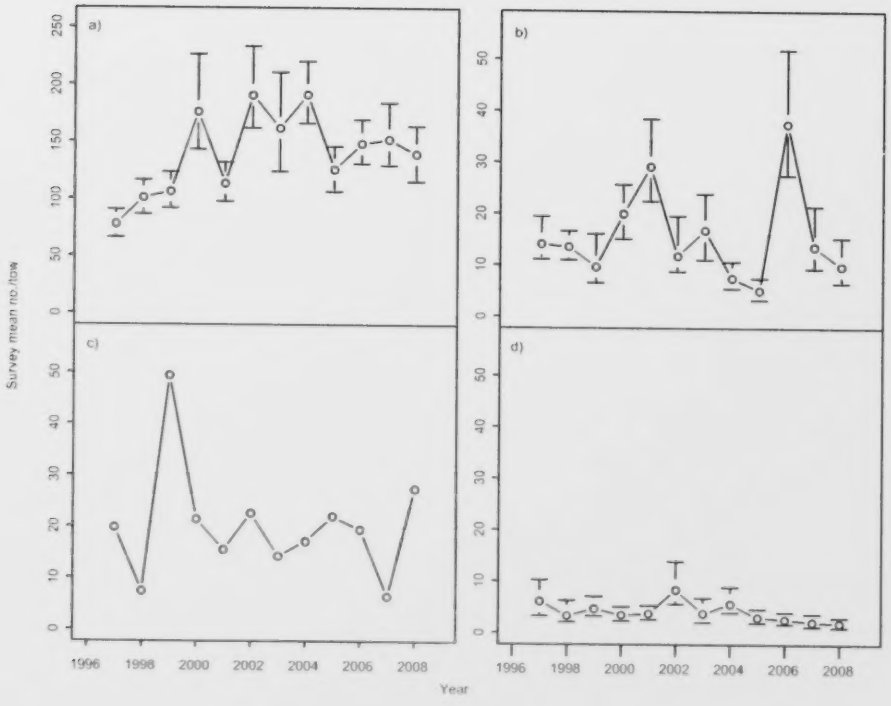

Fig. 26. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Cape Spencer area of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

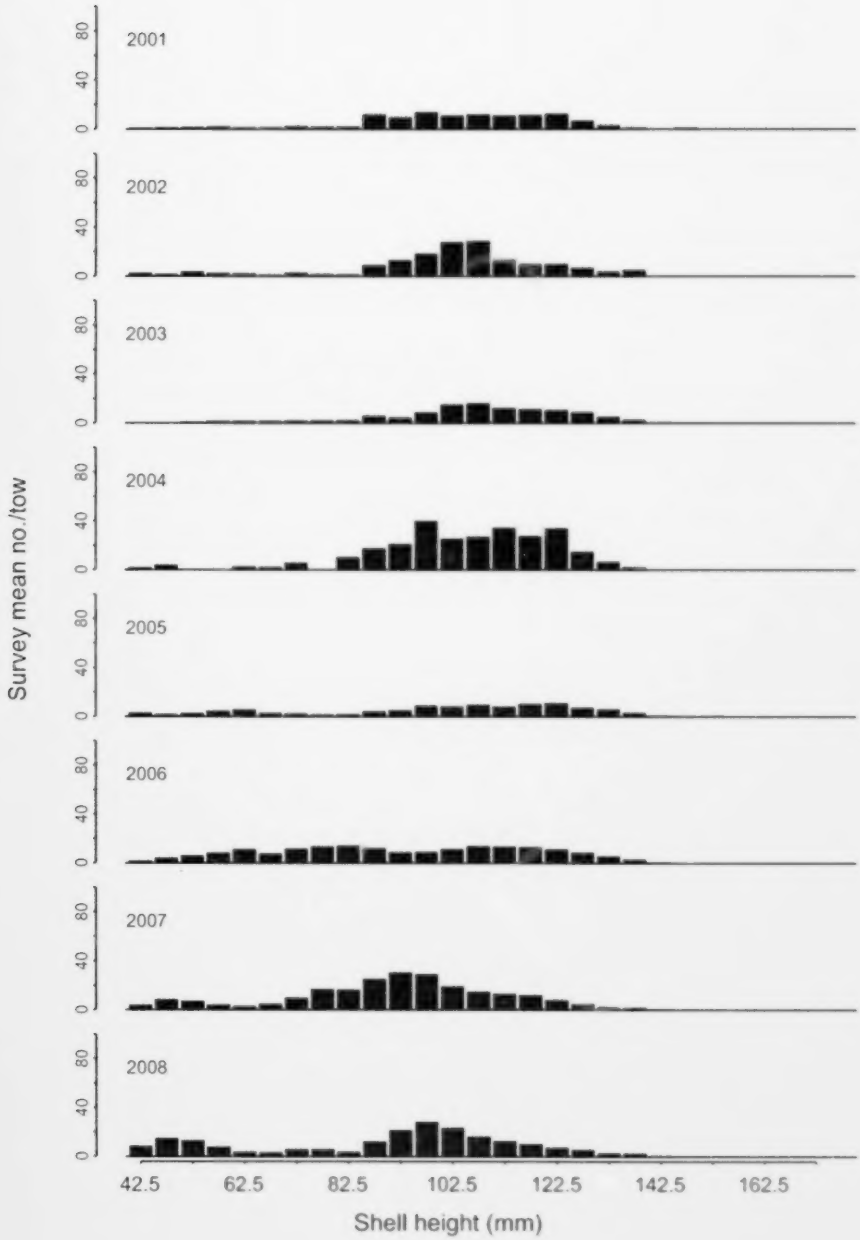

Fig. 27. Scallop shell height frequencies (mean number/tow) from the surveys of the Middle Bay North area of Scallop Production Area 1B.

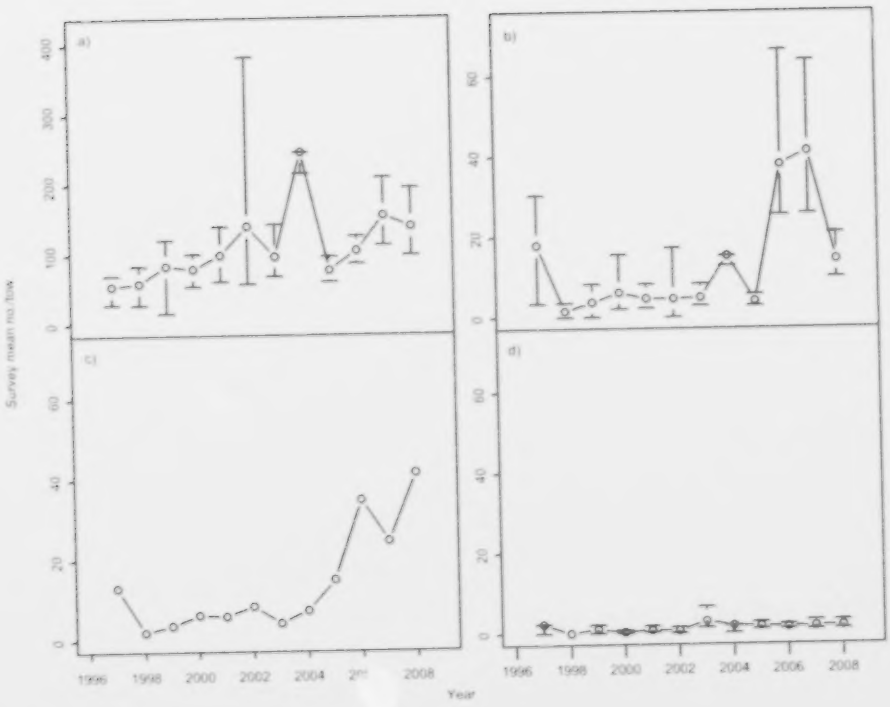

Fig. 28. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Middle Bay North area of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

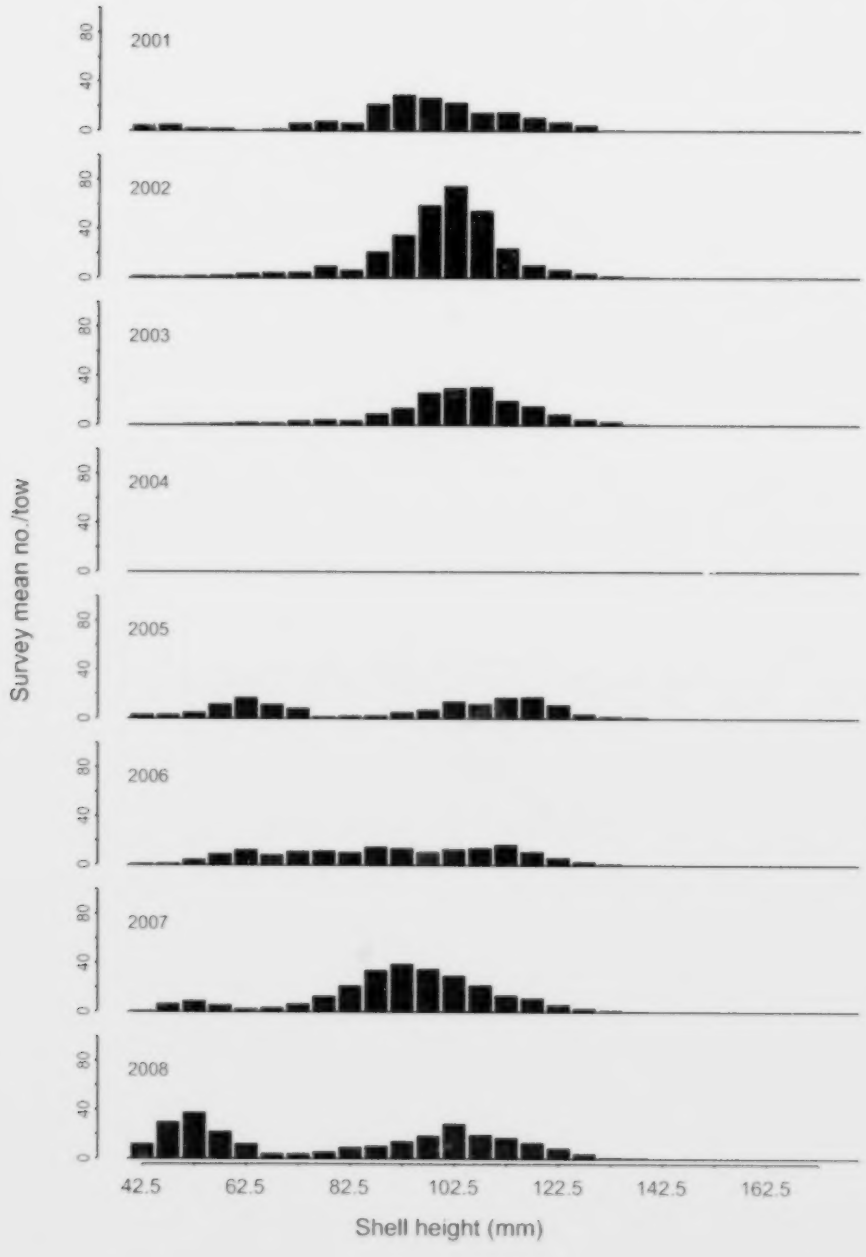

Fig. 29. Scallop shell height frequencies (mean number/tow) from the surveys of the 28C area of Scallop Production Area 1B.

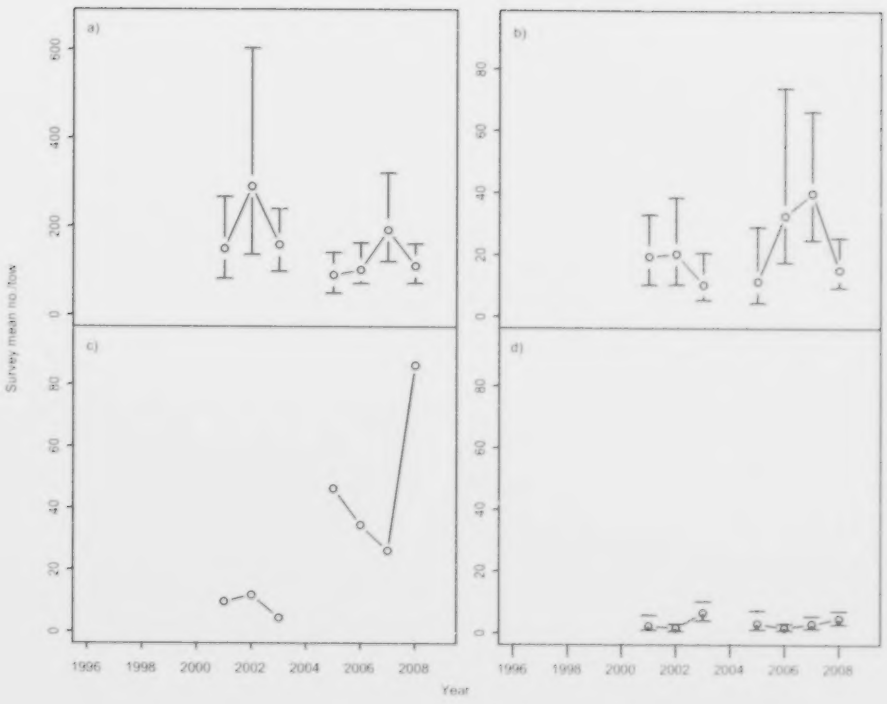

Fig. 30. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the 28C area of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

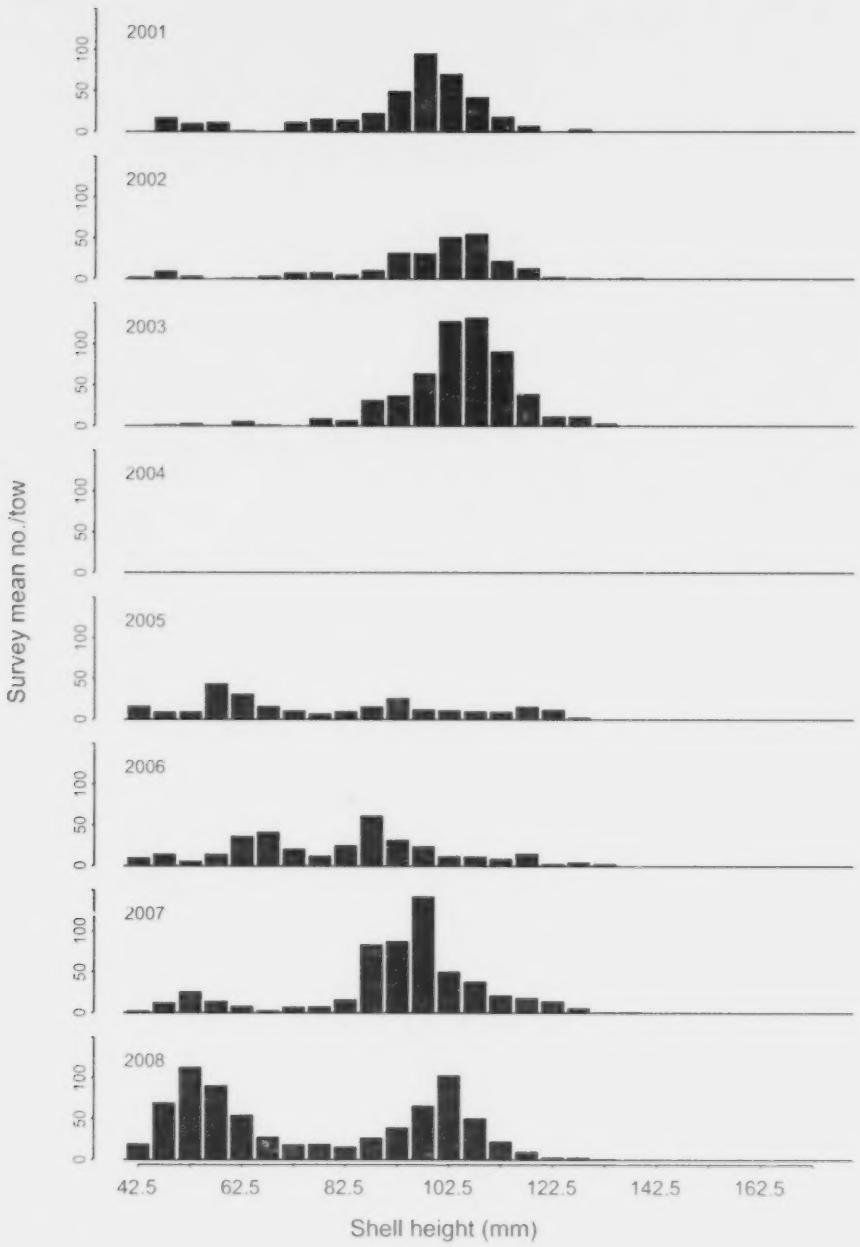

Fig. 31. Scallop shell height frequencies (mean number/tow) from the surveys of the Advocate area (SFA 28D) of Scallop Production Area 1B.

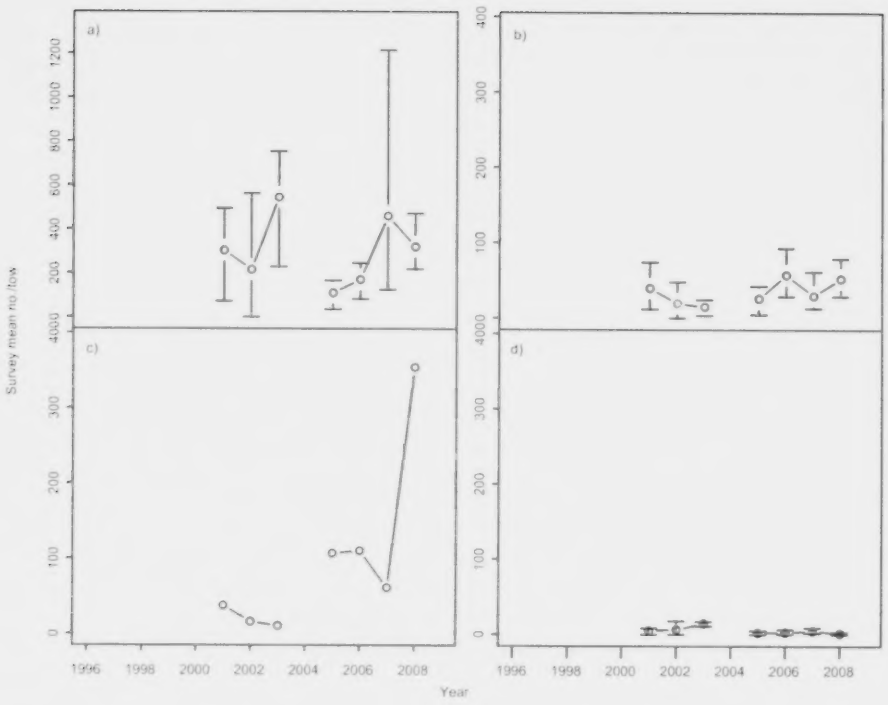

Fig. 32. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Advocate area (SFA 28D) of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

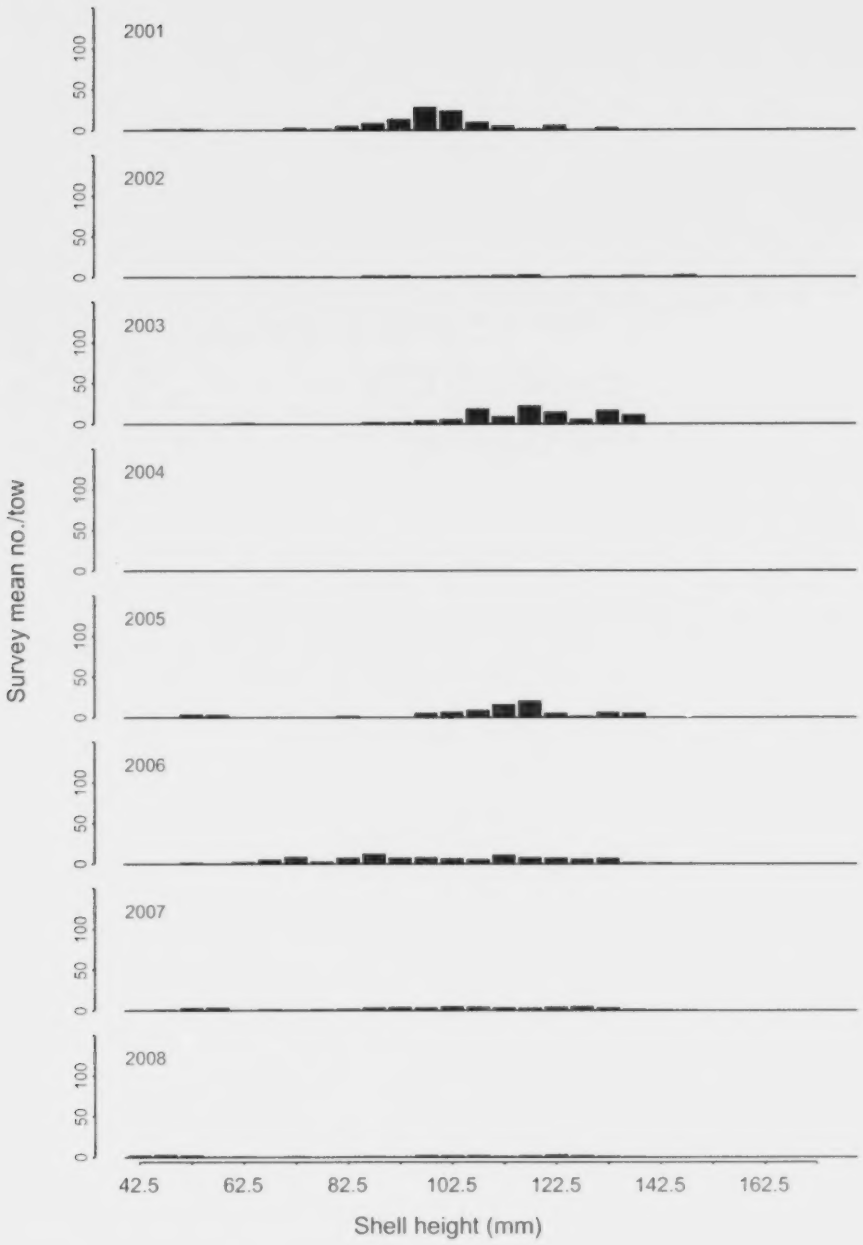

Fig. 33. Scallop shell height frequencies (mean number/tow) from the surveys of the Outer area (SFA 28D) of Scallop Production Area 1B.

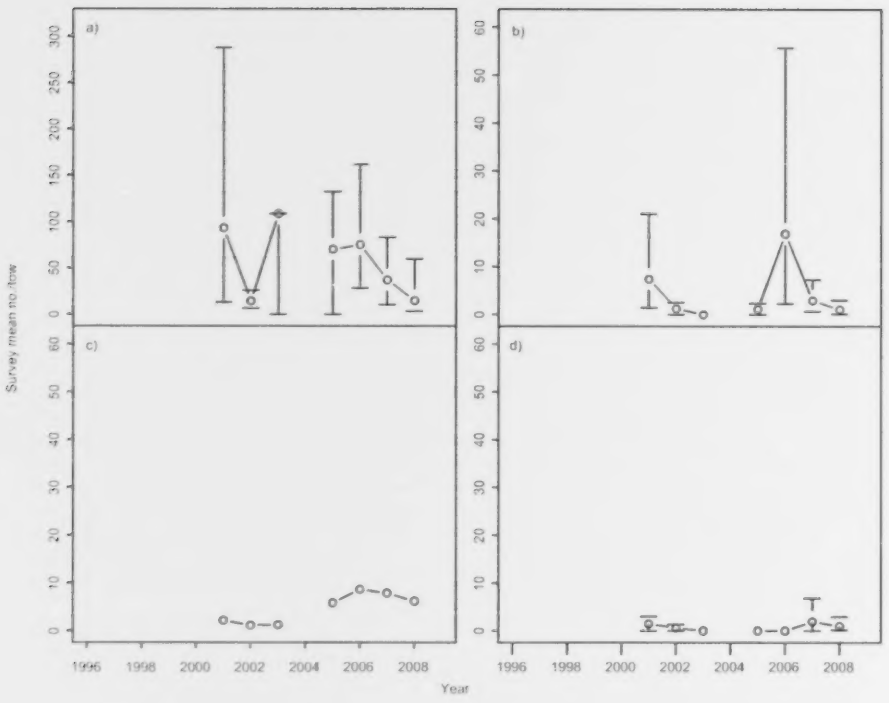

Fig. 34. Survey abundance index (mean number/tow) for a) commercial size ($\geq$ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers ($\geq$ 80 mm) scallops in the Outer area (SFA 28D) of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

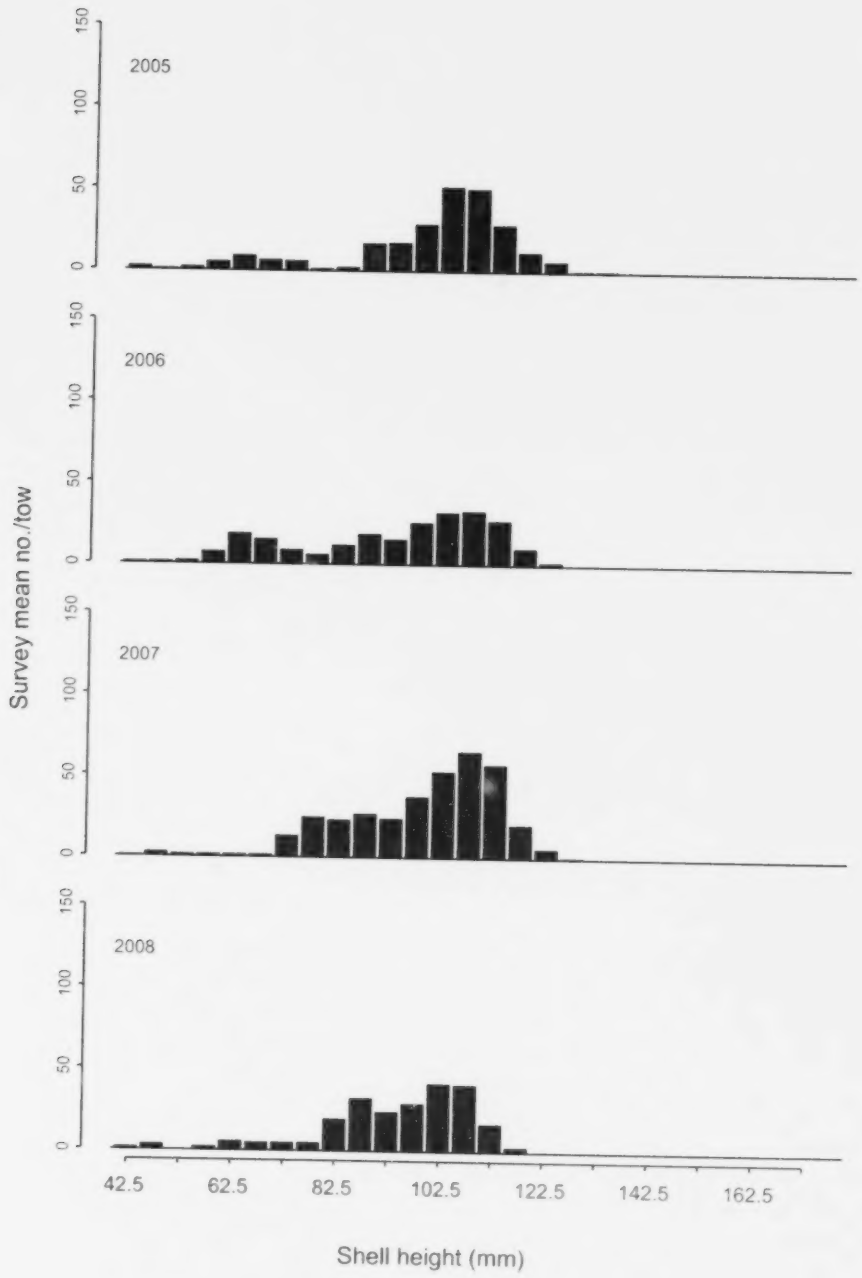

Fig. 35. Scallop shell height frequencies (mean number/tow) from the surveys of the Spencer's Island area (SFA 28D) of Scallop Production Area 1B.

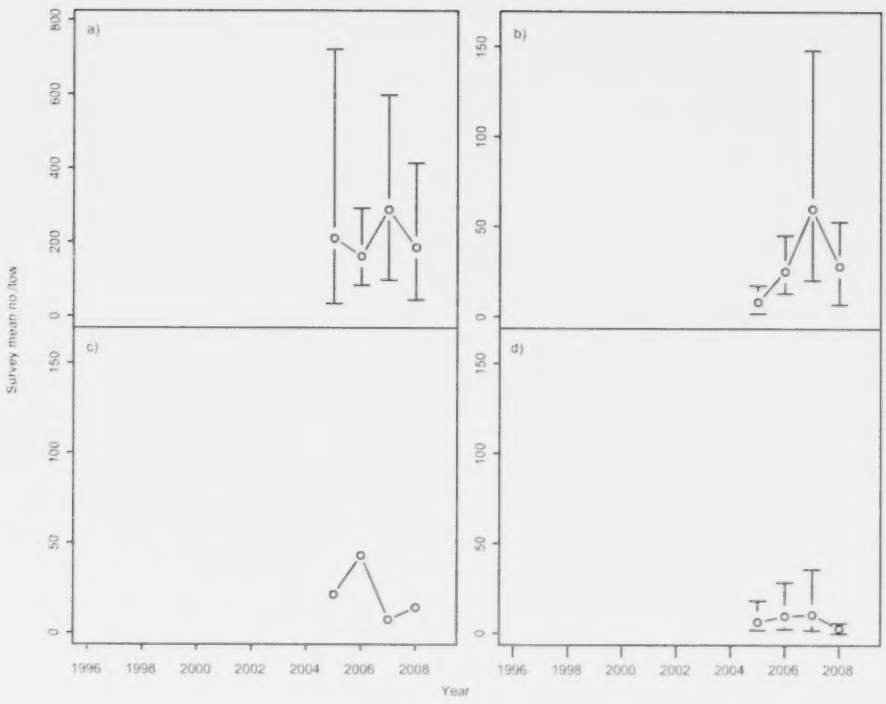

Fig. 36. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Spencer's Island area (SFA 28D) of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

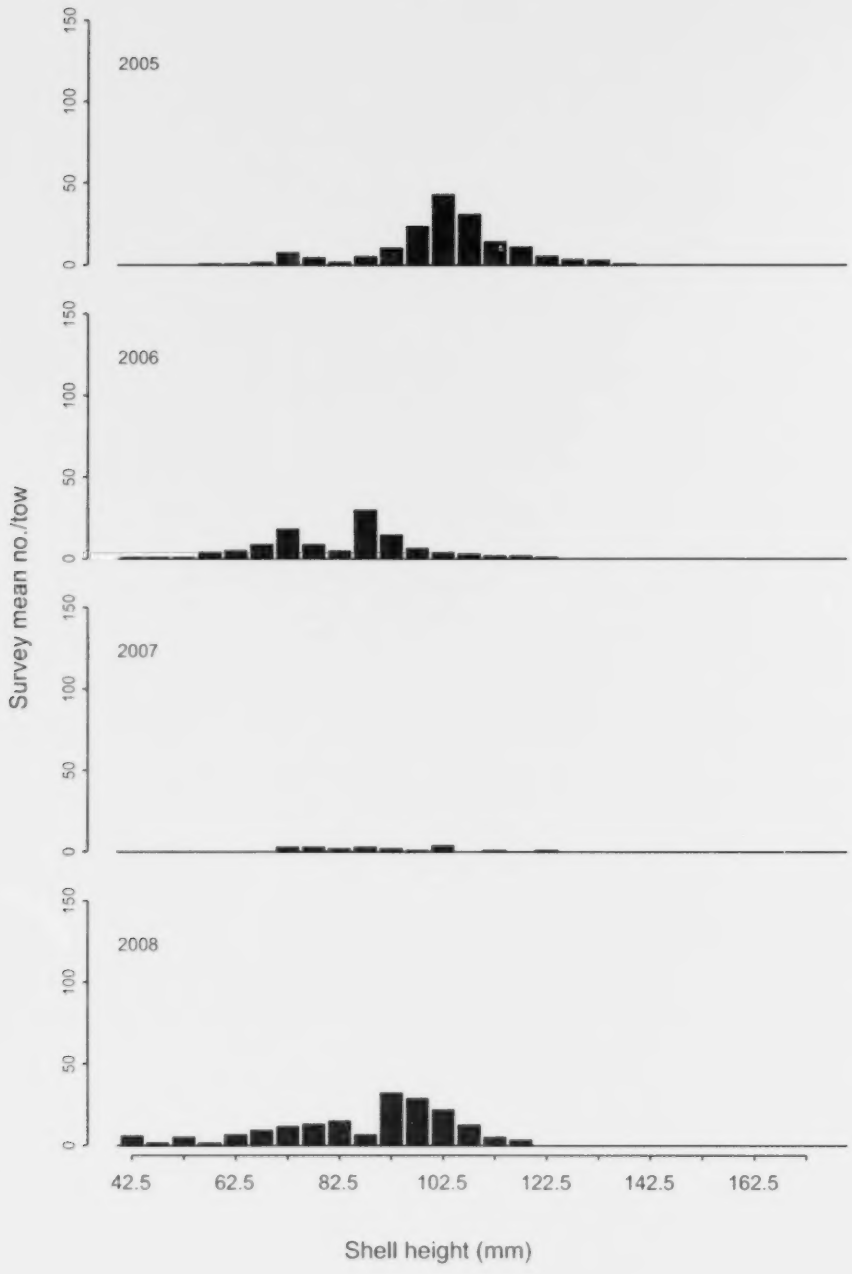

Fig. 37. Scallop shell height frequencies (mean number/tow) from the surveys of the Scots Bay area (SFA 28D) of Scallop Production Area 1B.

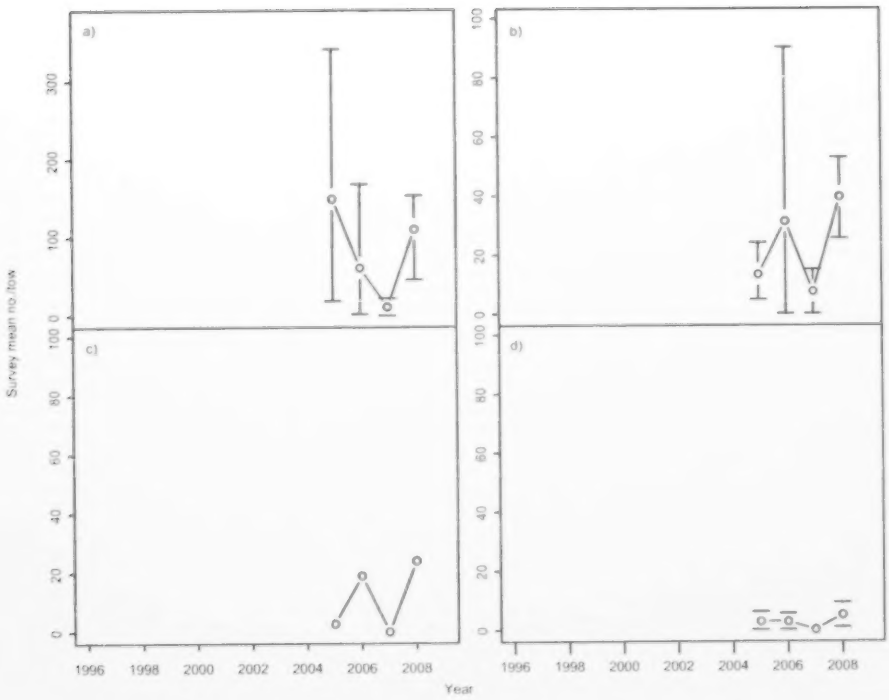

Fig. 38. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Scots Bay area (SFA 28D) of Scallop Production Area 1B. 95 percent bootstrap confidence intervals are included.

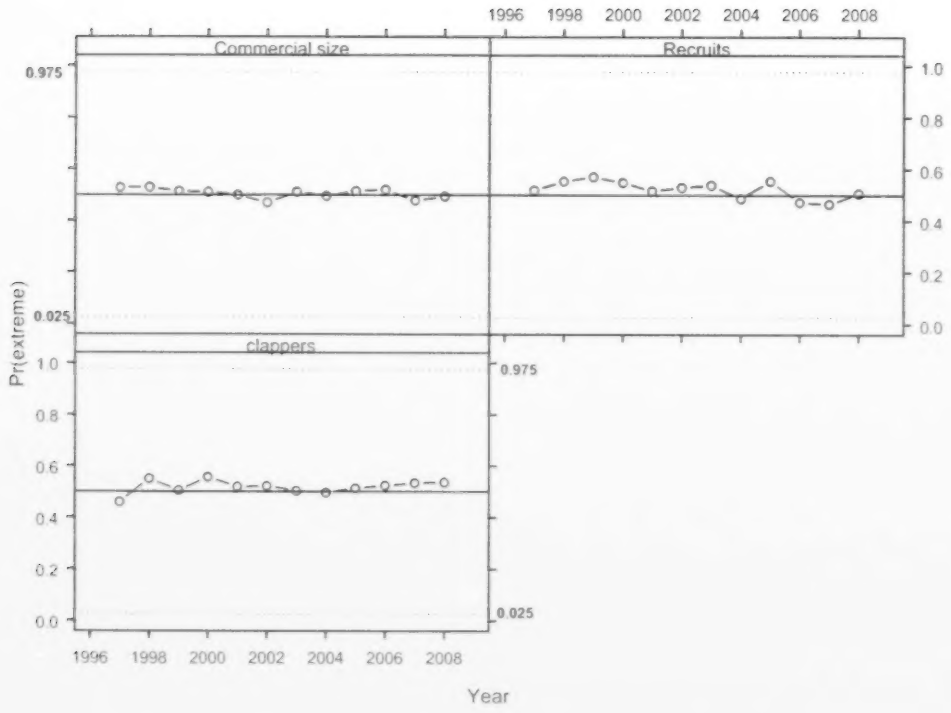

Fig. 39. Probabilities of getting larger observations than obtained for survey estimates of Biomass, recruits and clappers for the delay-difference model in SPA 1B. Dotted lines indicate probabilities of 0.025 and 0.975.

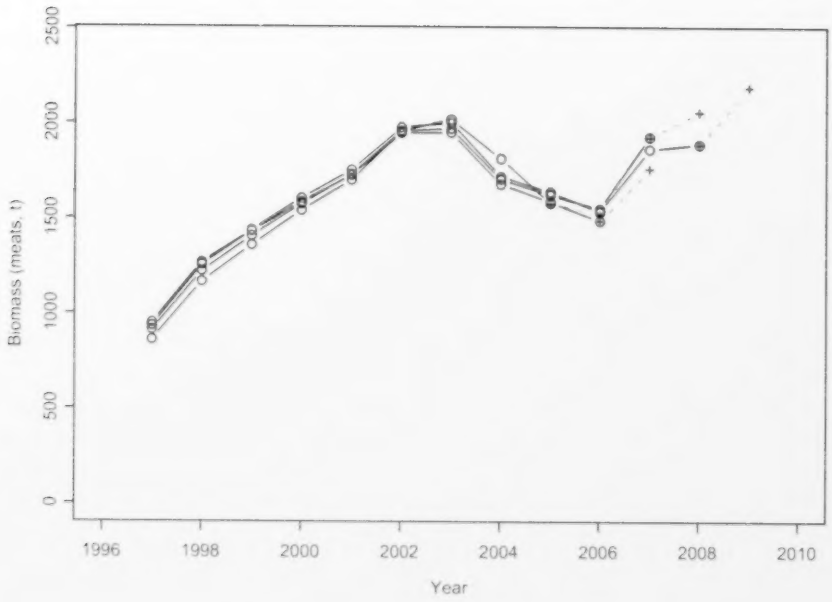

Fig. 40. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size scallops ($\geq$ 80 mm shell height) in the current year in Scallop Production Area 1B. Predictions and current year estimates were produced from the delay-difference population model. Prediction for 2009 made assuming a 2008/2009 catch of 100 t.

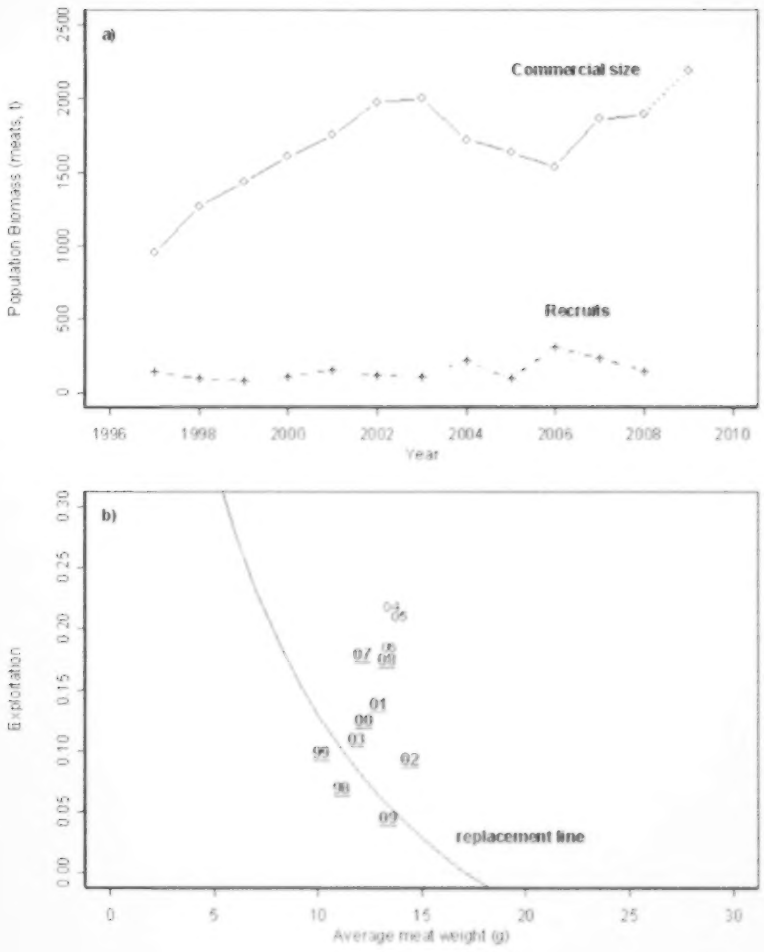

Fig. 41. a) Estimated population biomass for commercial and recruit size scallops in Scallop Production Area 1B. The prediction for 2009 was made assuming the interim TAC of 100 t for 2008/2009. b) Exploitation rate (Catch/Commercial size Biomass) versus average meat weight of the commercial size scallops. The replacement line refers to the increase in biomass due to growth discounted for natural mortality. Points are labelled by the fishing year (or end of fishing year for Full Bay fleet,i.e., 09 for 2008/2009). Those years printed in larger underlined font (and coloured red) indicate that the population biomass increased after the fishery. Years in the smaller font (and coloured black) were those in which the biomass declined after the fishery. Refer to panel a) for the trends in biomass.

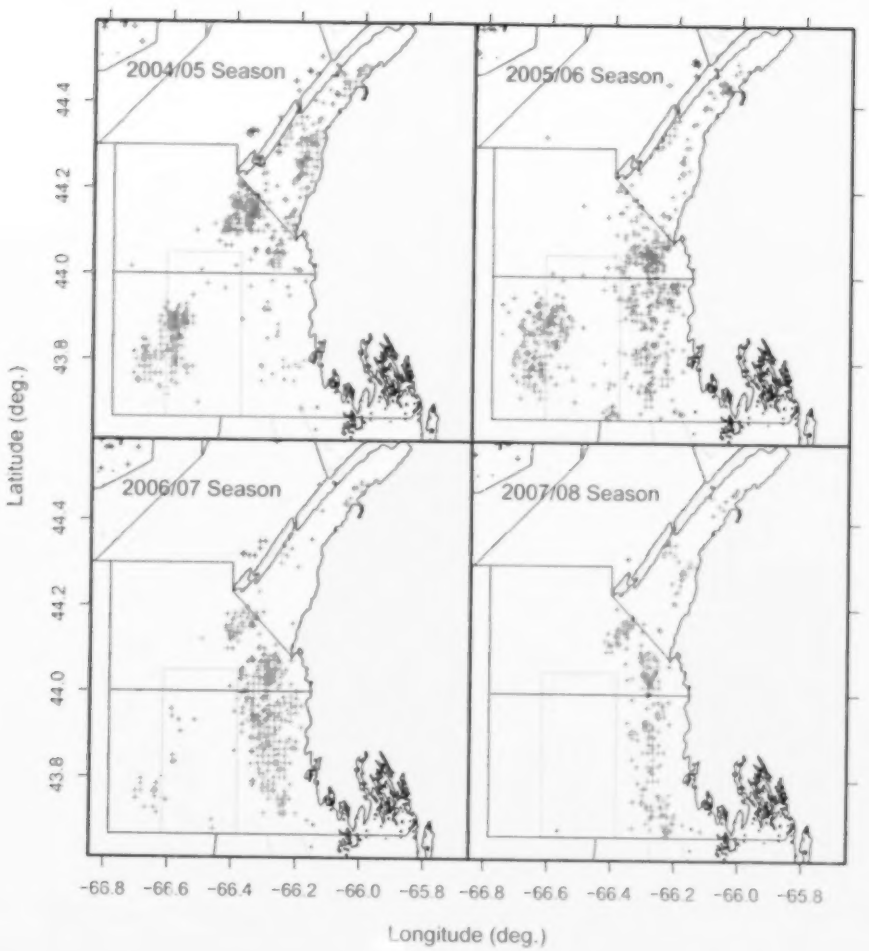

Fig. 42. Fishing locations based upon commercial fishing logs in Scallop Production Area 3. Closed area instituted in the 2007/2008 fishing to protect small scallops is indicated.

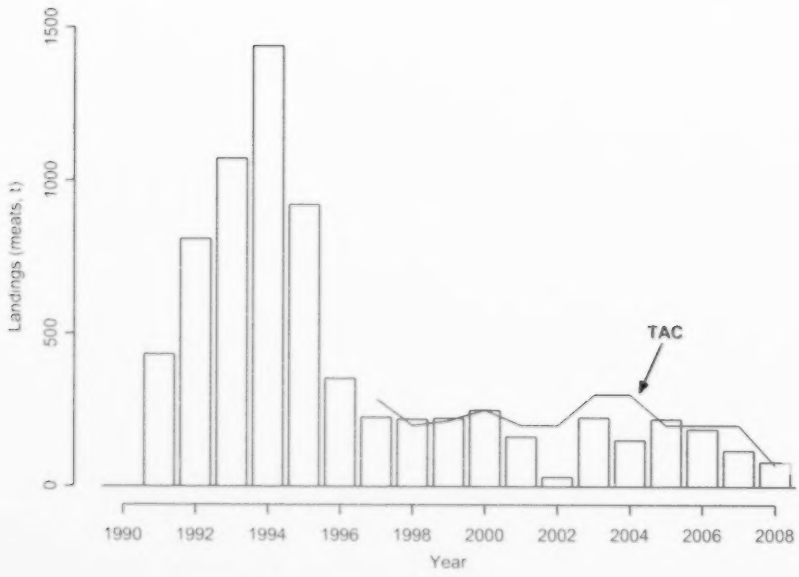

Fig. 43. Scallop landings (meats, t) in Scallop Production Area 3.

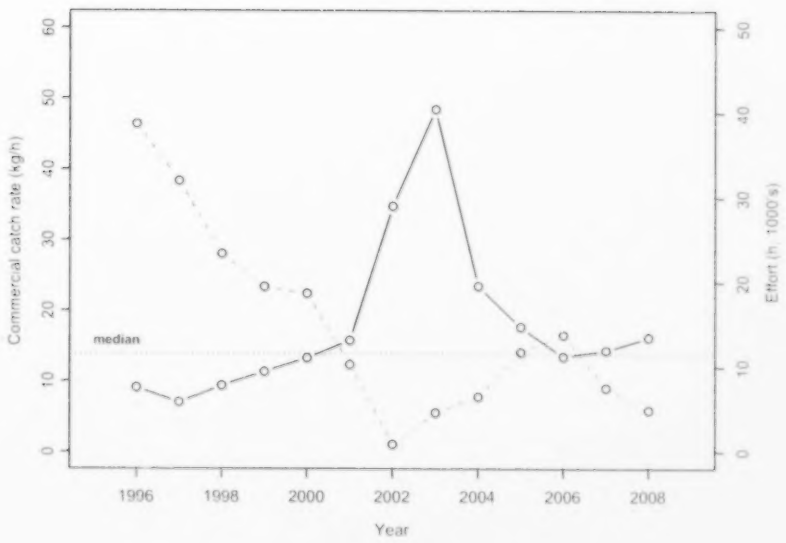

Fig. 44. Commercial catch rate (kg/h) and commercial fishing effort (hours) for scallops in Scallop Production Area 3. Median catch rate over the 1996 to 2007 fishing seasons indicated.

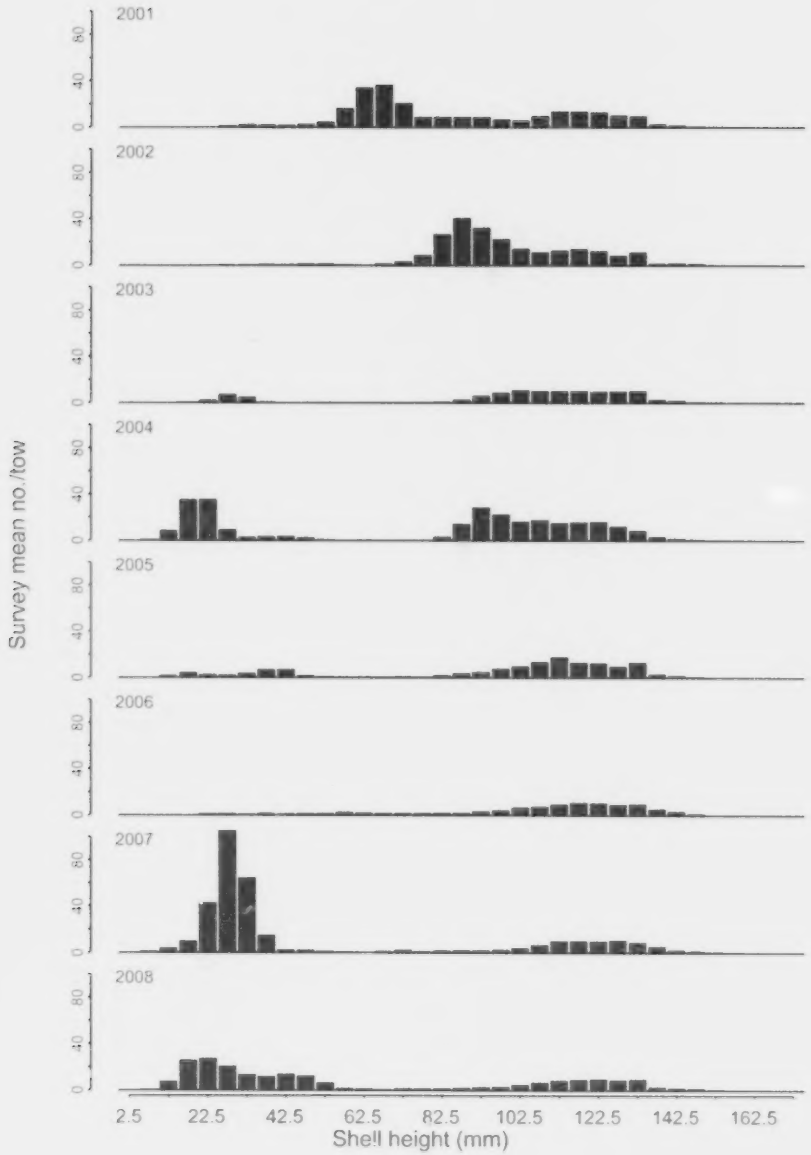

Fig. 45. Scallop shell height frequencies from the 2001 to 2008 surveys of the Brier/Lurcher portion of Scallop Production Area 3.

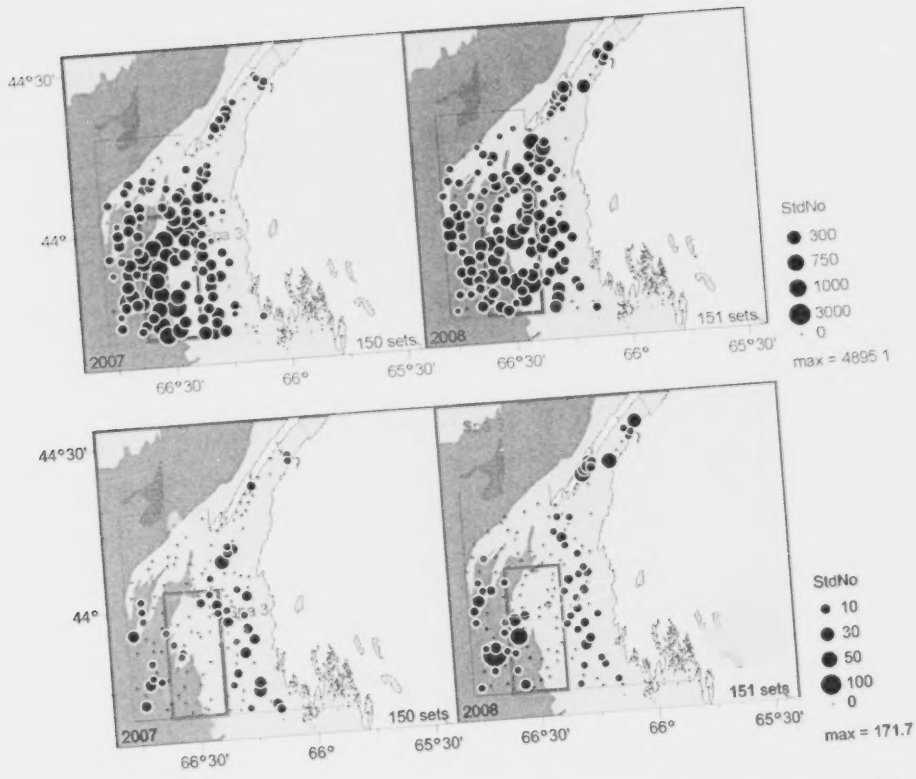

Fig. 46. Spatial distribution of scallop catches for shell height $\leq$ 50 mm (upper panel) and 50 to 70 mm (lower panel) from surveys of Scallop Production Area 3 for 2007 and 2008. Closed area for protection of small scallops indicated.

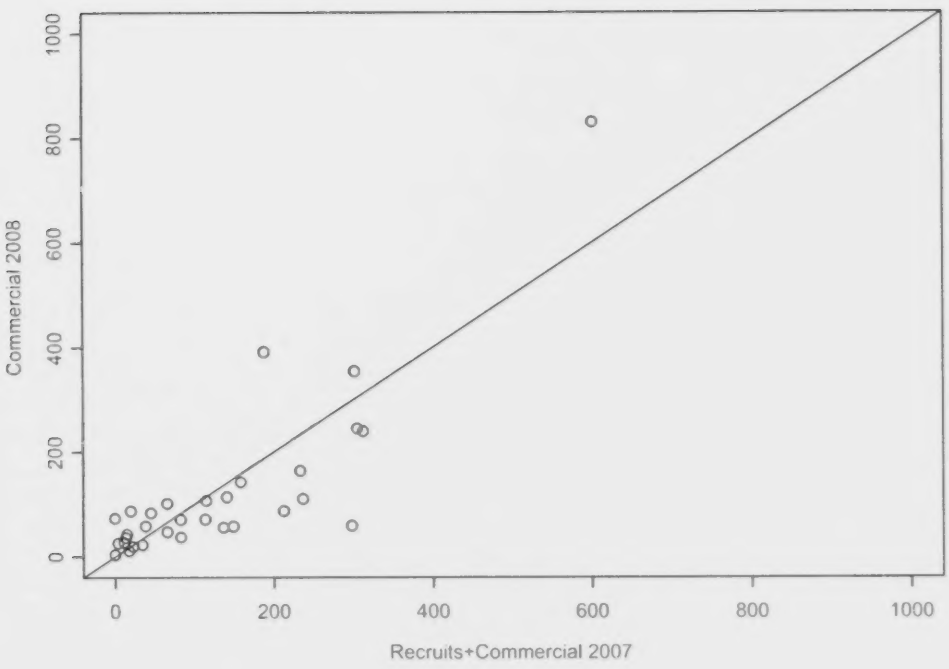

Fig. 47. Comparing numbers of commercial size scallops (≥80 mm shell height) and recruits (65 to 79 mm shell height) caught in 2007 and commercial size scallops 2008 in the survey stations common to both of the surveys in SPA 3. Solid line indicates 1:1 line.

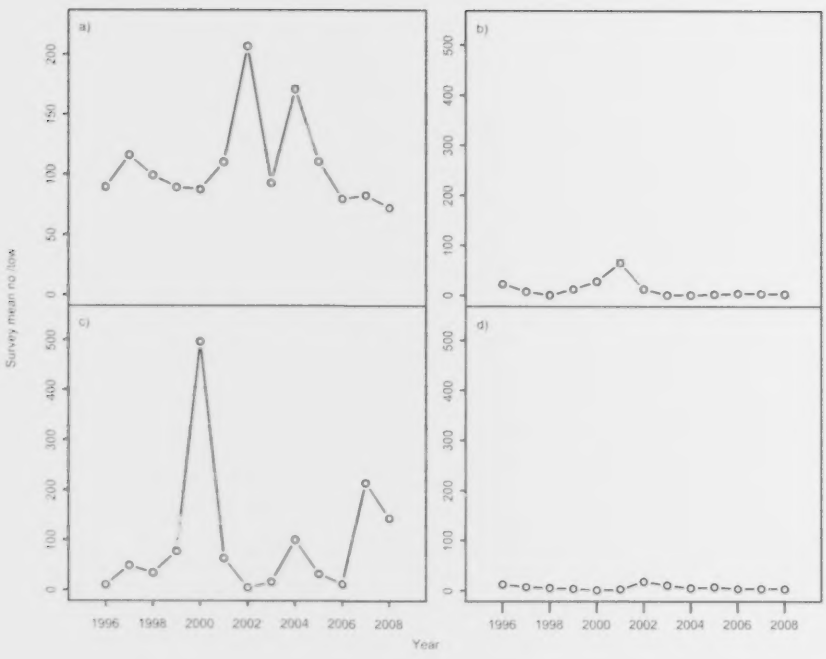

Fig. 48. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the Brier/Lurcher area of SPA 3.

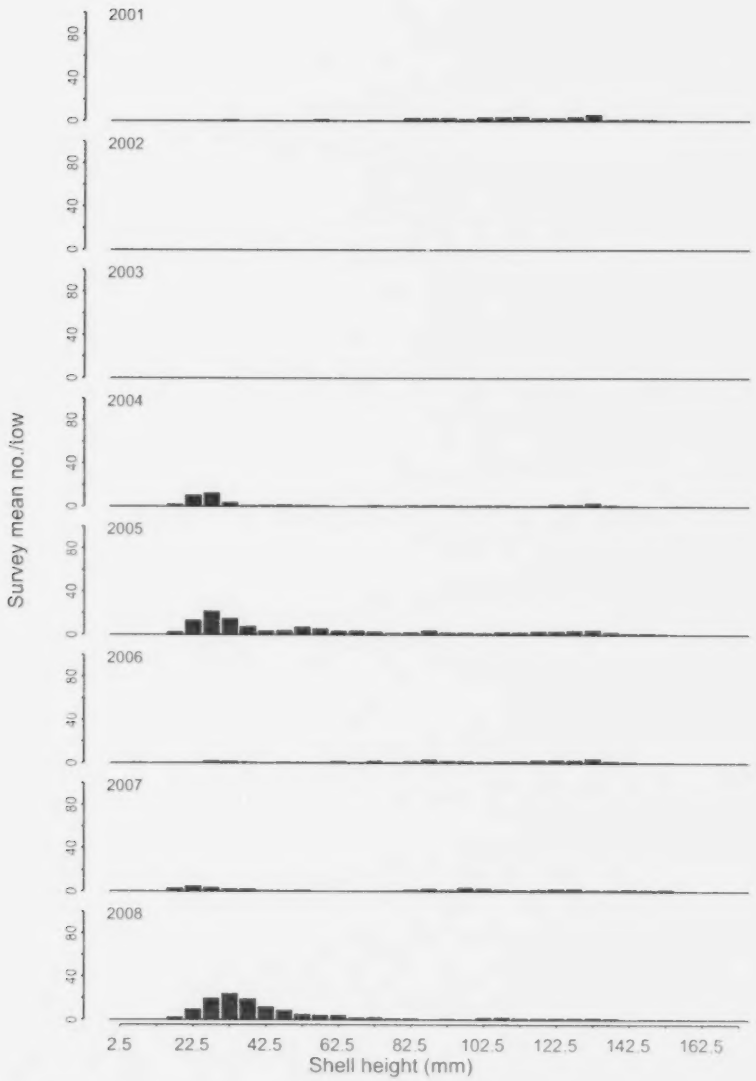

Fig. 49. Scallop shell height frequencies from the 2001 to 2008 surveys of the St. Mary's Bay portion of Scallop Production Area 3.

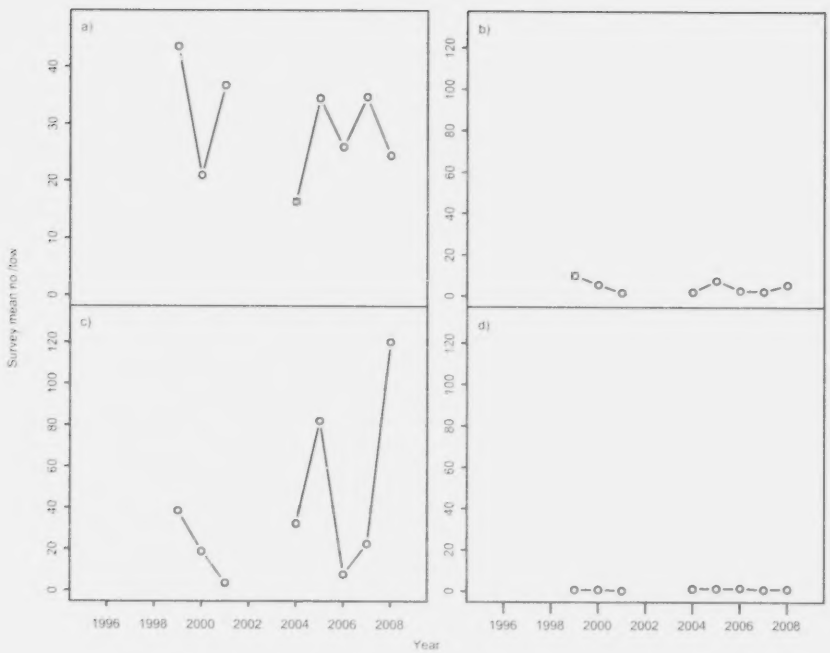

Fig. 50. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) scallops in the St. Mary's Bay area of SPA 3.

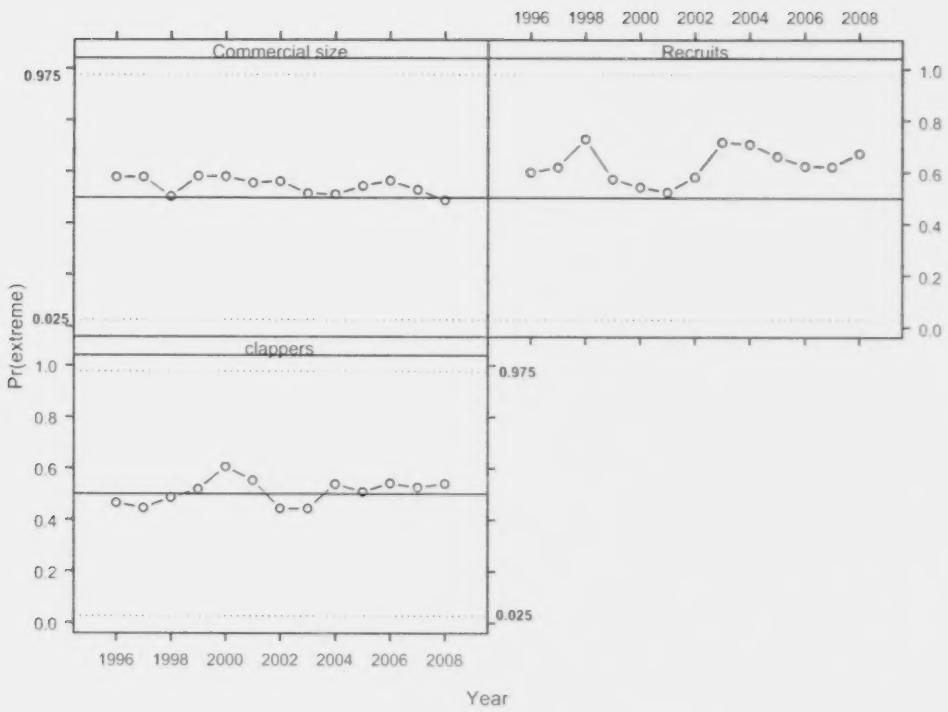

Fig. 51. Probabilities of getting larger observation than obtained for survey estimates of Biomass, recruits and clappers. Dotted lines indicate probabilities of 0.025 and 0.975.

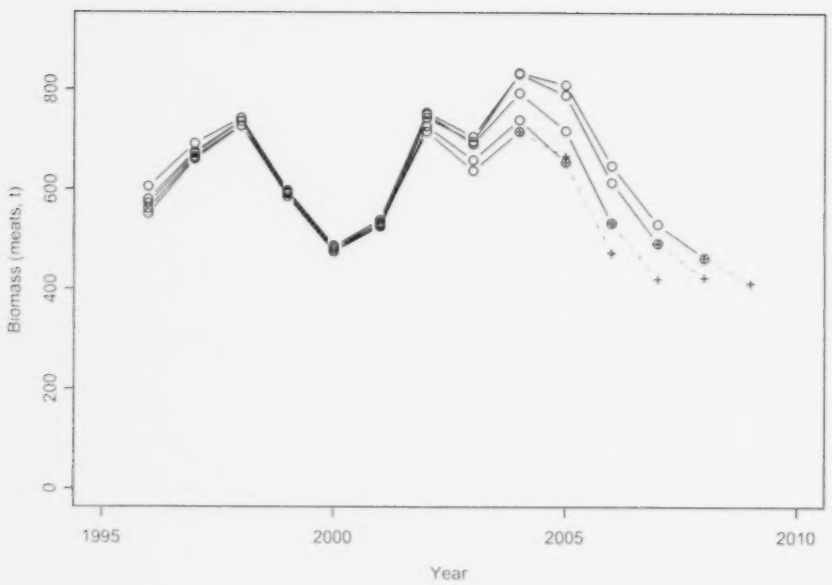

Fig. 52. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size scallops (≥ 80 mm shell height) in the current year in Scallop Production Area 3. Predictions and current year estimates were produced from the delay-difference population model. Prediction for 2009 made assuming a 2008/2009 catch of 50 t.

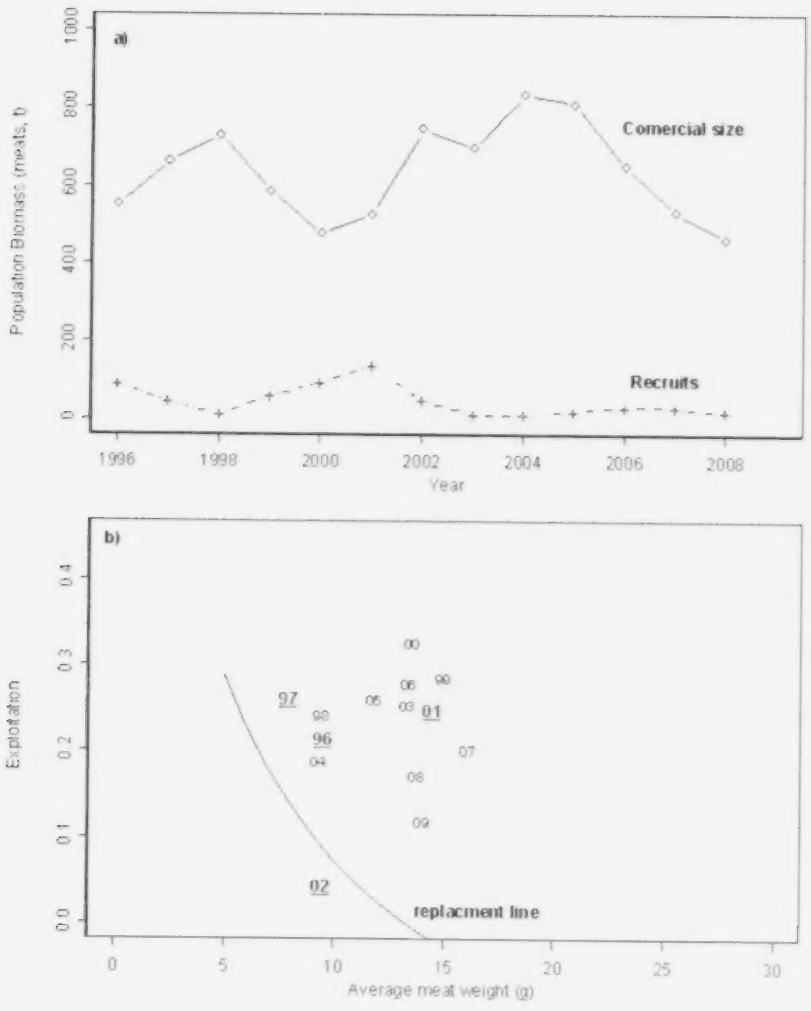

Fig. 53. a) Estimated population biomass for commercial and recruit size scallops in Scallop Production Area 3. The predicted biomass for 2009 was based on the interim TAC of 50 t. b) Exploitation rate (Catch/Commercial size Biomass) versus average meat weight of the commercial size scallops. The replacement line refers to the increase in biomass due to growth discounted for natural mortality. Points are labelled by the end of fishing year (i.e., 09 for 2008/2009). Those years printed in larger font (and coloured red) indicate that the population biomass increased after the fishery. Years in the smaller font (and coloured black) were those in which the biomass declined after the fishery. Refer to panel a) for the trends in biomass.

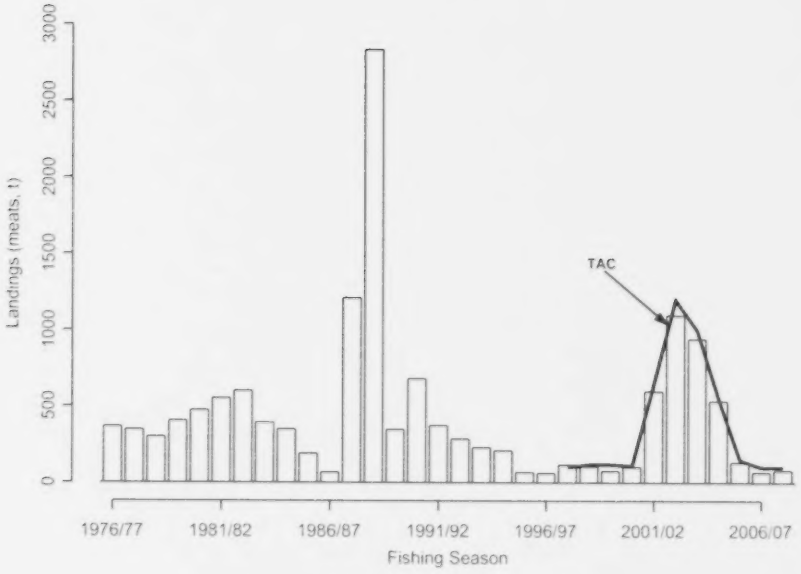

Fig. 54. Trends in scallop catch (meats, t) from SPA 4. TACs were initiated in 1997.

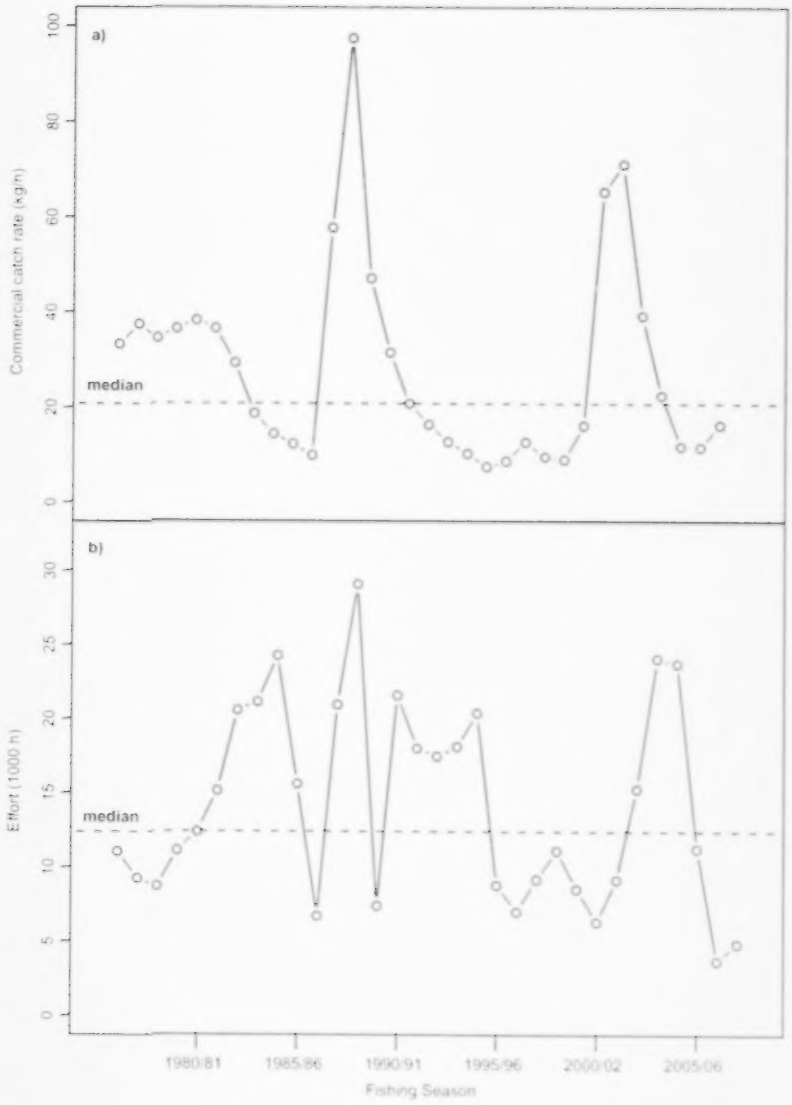

Fig. 55. Trends in a) scallop catch rate (kg/h) and b) scallop fishing effort (1000's hours) from SPA 4. Median levels over the 1976/1977 to 2006/2007 fishing seasons indicated.

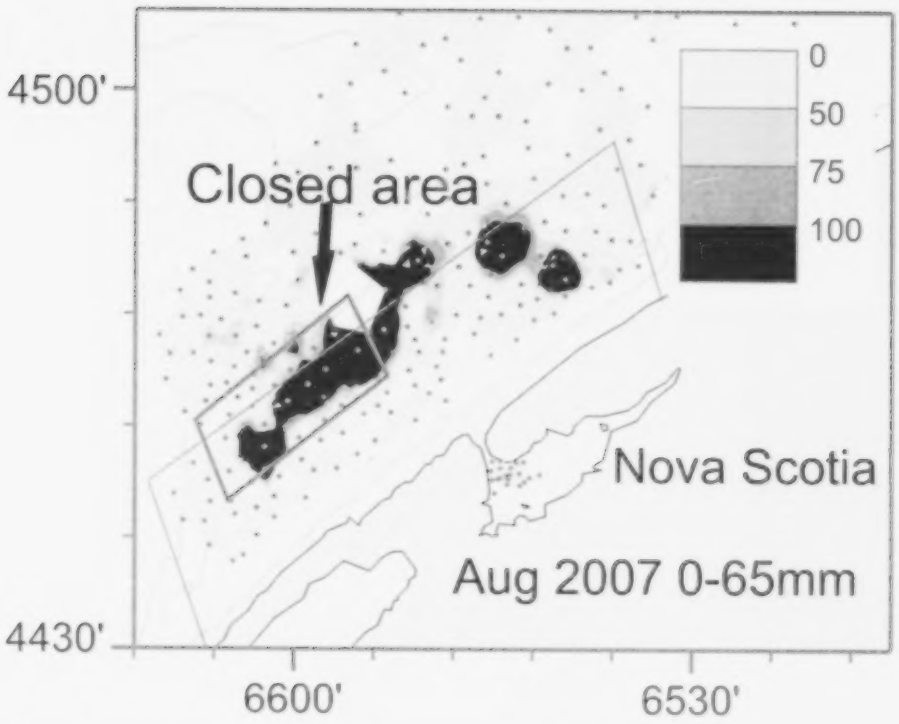

Fig. 56. Spatial distribution of catches from the 2007 survey of Scallop Production Areas 1 and 4 for pre-recruit size (< 65 mm shell height) scallops. Closed area proposed by Full Bay Fleet to protect small scallops indicated. This closed area was implemented on October 2, 2007 as Variation Order 2007-123. Contouring was derived using Delauney triangles and inverse distance weight interpolation. Positions of tow locations are indicated.

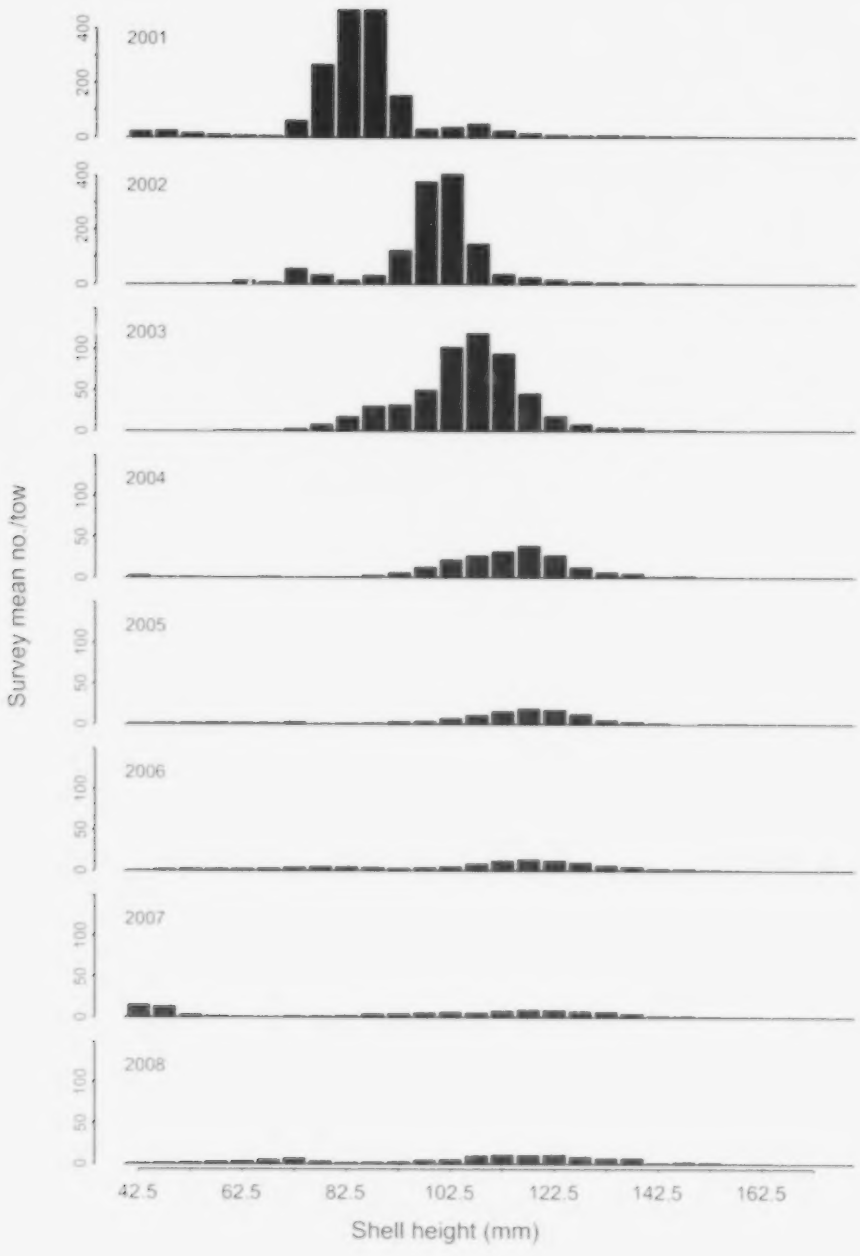

Fig. 57. Comparison of shell height frequencies from the 2001 to 2008 surveys of SPA 4. Note change in scale for y-axis after 2002.

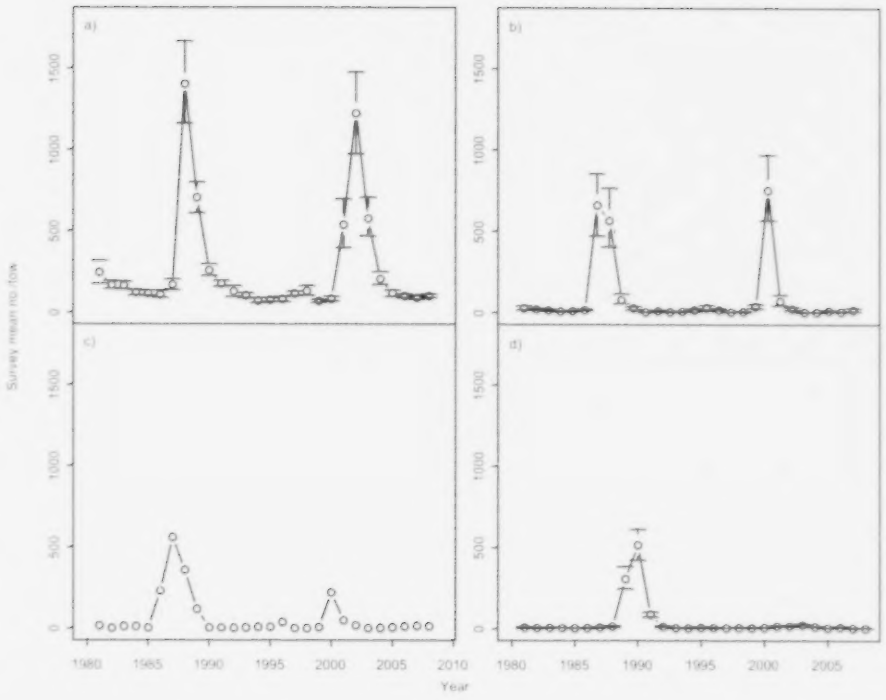

Fig. 58. Survey abundance index (mean number/tow) for a) commercial size (≥ 80 mm shell height), b) recruit (65–79 mm), c) pre-recruit (40–64 mm) and d) clappers (≥ 80 mm) for scallops in Scallop Production Area 4. 95 percent bootstrap confidence intervals are included.

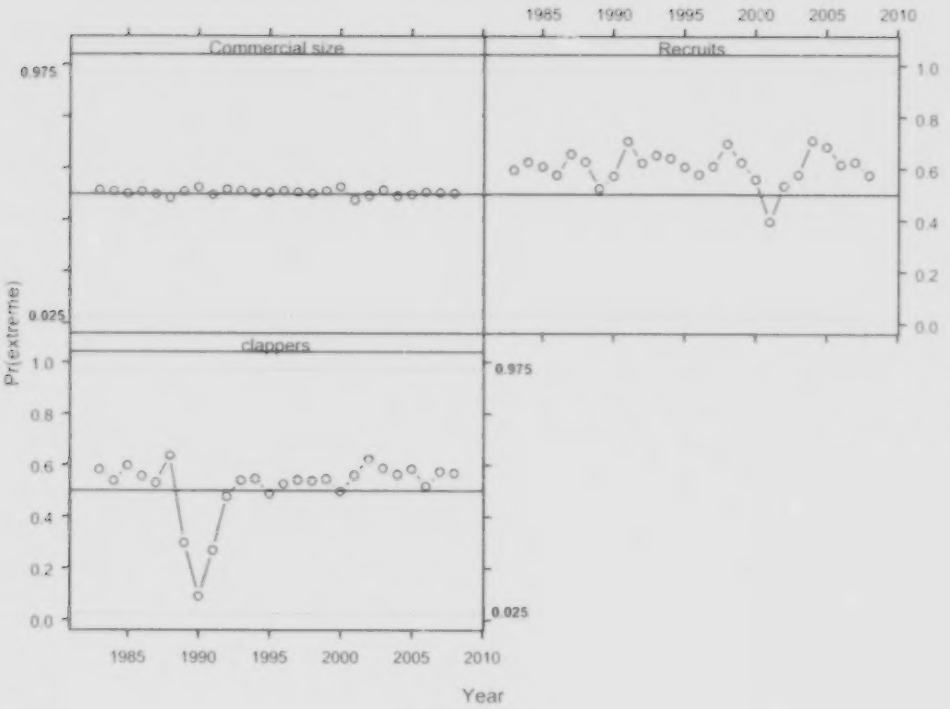

Fig. 59. Probabilities of getting larger observation than obtained for survey estimates of Biomass, recruits and clappers. Dotted lines indicate probabilities of 0.025 and 0.975.

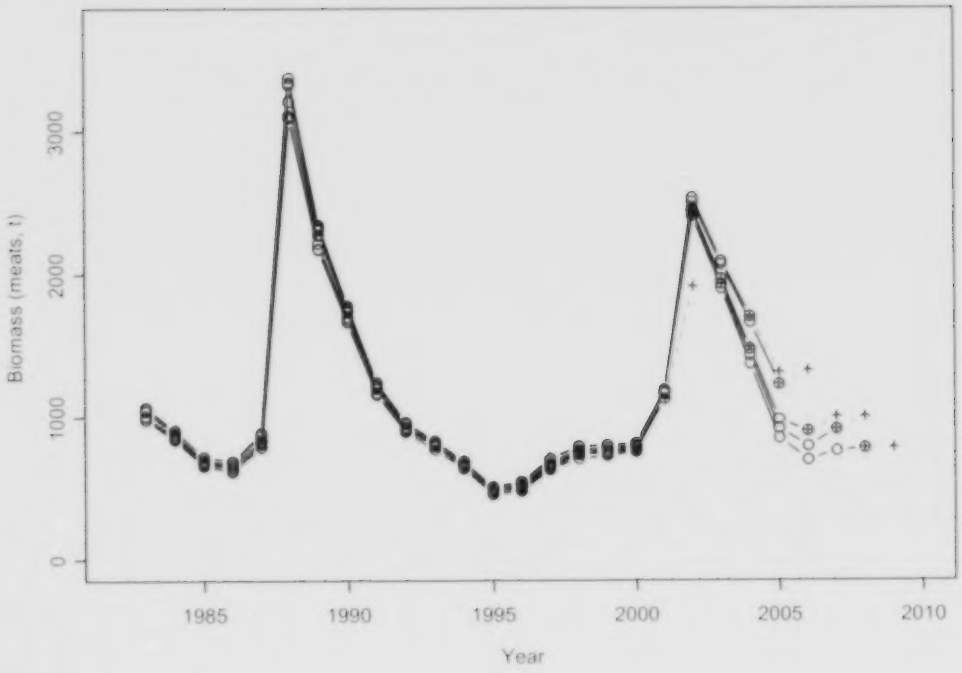

Fig. 60. Comparison of predicted biomass from the previous year with the estimated biomass of commercial size scallops (≥ 80 mm shell height) in the current year in Scallop Production Area 4. Predictions and current year estimates were produced from the delay-difference population model. Prediction for 2009 made assuming a 2008/2009 catch of 100 t.

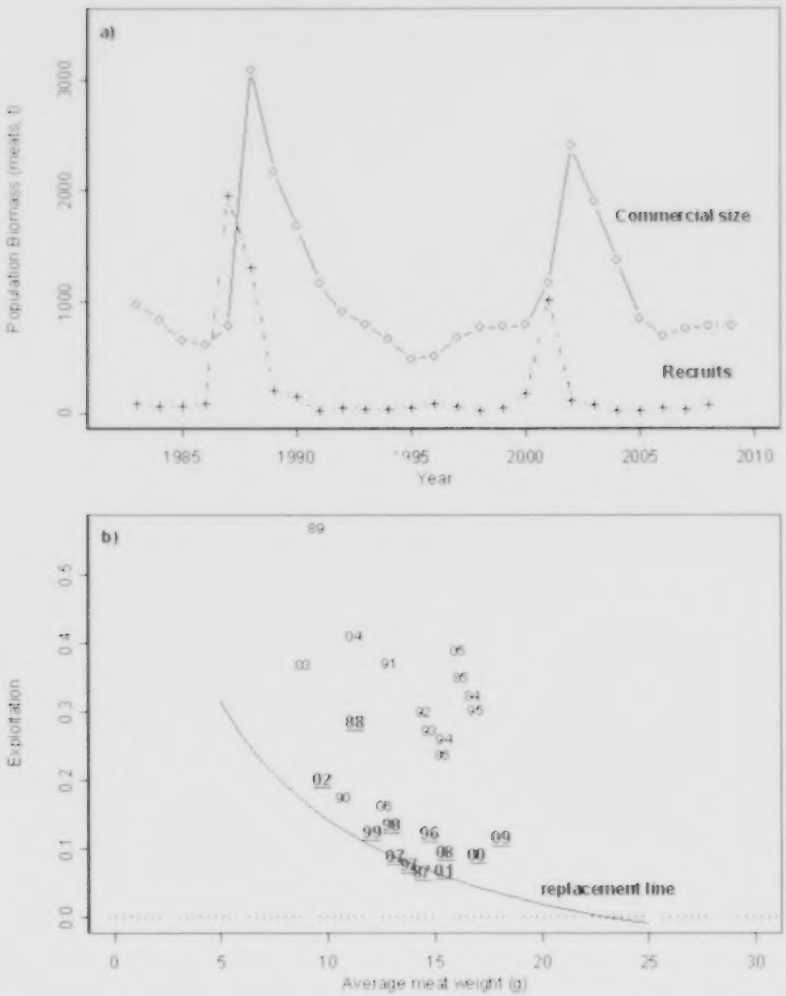

Fig. 61. a) Estimated population biomass for commercial and recruit size scallops in Scallop Production Area 4. The predicted biomass for 2009 was made for the interim TAC of 100 t. b) Exploitation rate (Catch/Commercial size Biomass) versus average meat weight of the commercial size scallops. The replacement line refers to the increase in biomass due to growth discounted for natural mortality. Points are labelled by the end of fishing year (i.e., 09 for 2008/2009). Those years printed in larger underlined font (and coloured red) indicate that the population biomass increased after the fishery. Years in the smaller font (and coloured black) were those in which the biomass declined after the fishery. Refer to panel a) for the trends in biomass.

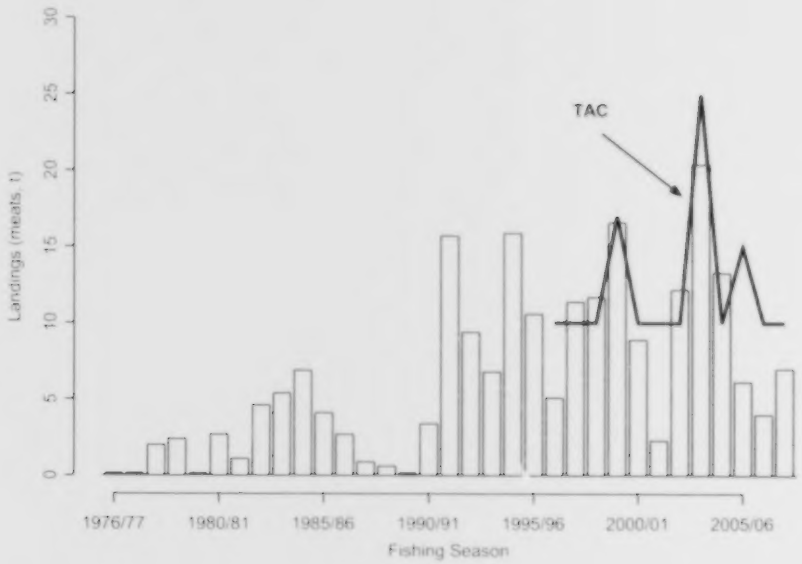

Fig. 62. Trends in scallop catch (meats, t) from SPA 5. TACs were initiated in 1997.

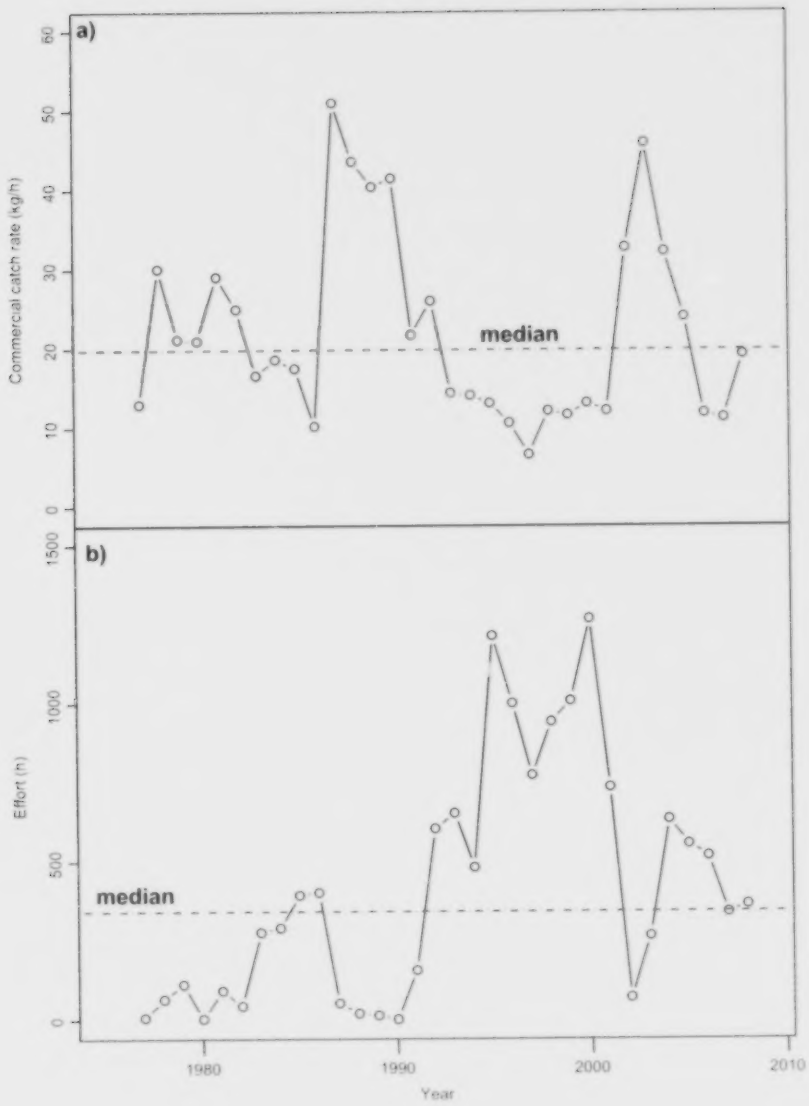

Fig. 63. Trends in a) commercial catch rate (kg/h) and b)commercial fishing effort (hours) for scallops in Scallop Production Area 5. Median levels over the 1976 to 2006 fishing seasons indicated.

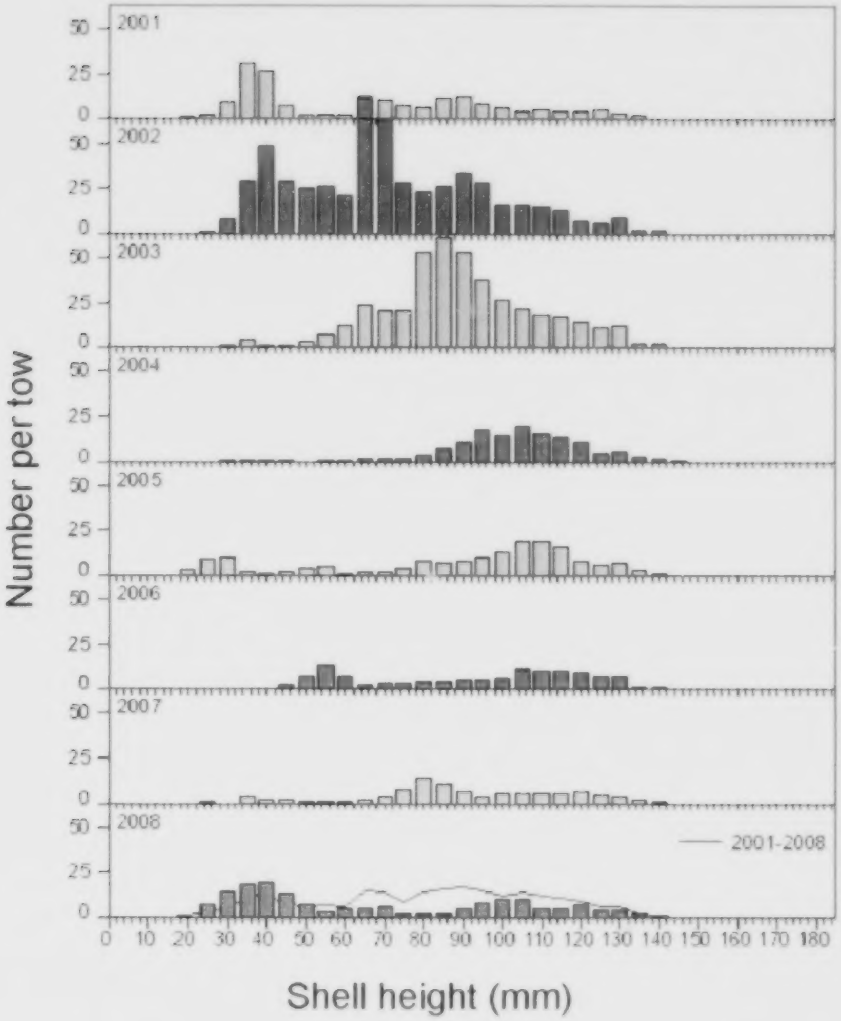

Fig. 64. Scallop shell height frequencies from the 2001 to 2008 surveys of Scallop Production Area 5.

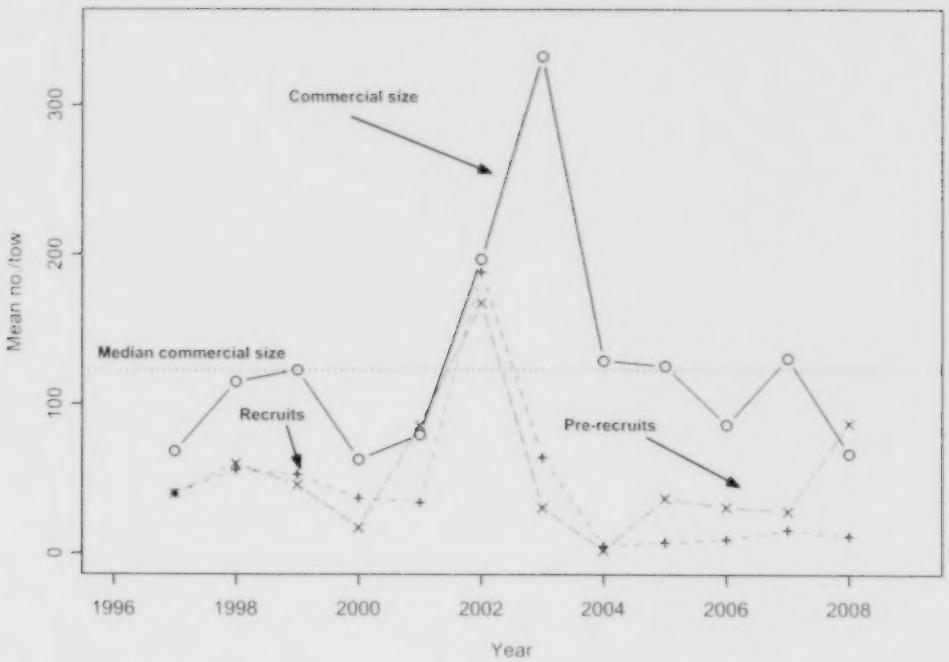

Fig. 65. Survey abundance index (mean number/tow) for commercial size scallops (≥ 80 mm shell height), recruits (65–79 mm shell height), and pre-recruits (< 65 mm shell height) in Scallop Production Area 5.

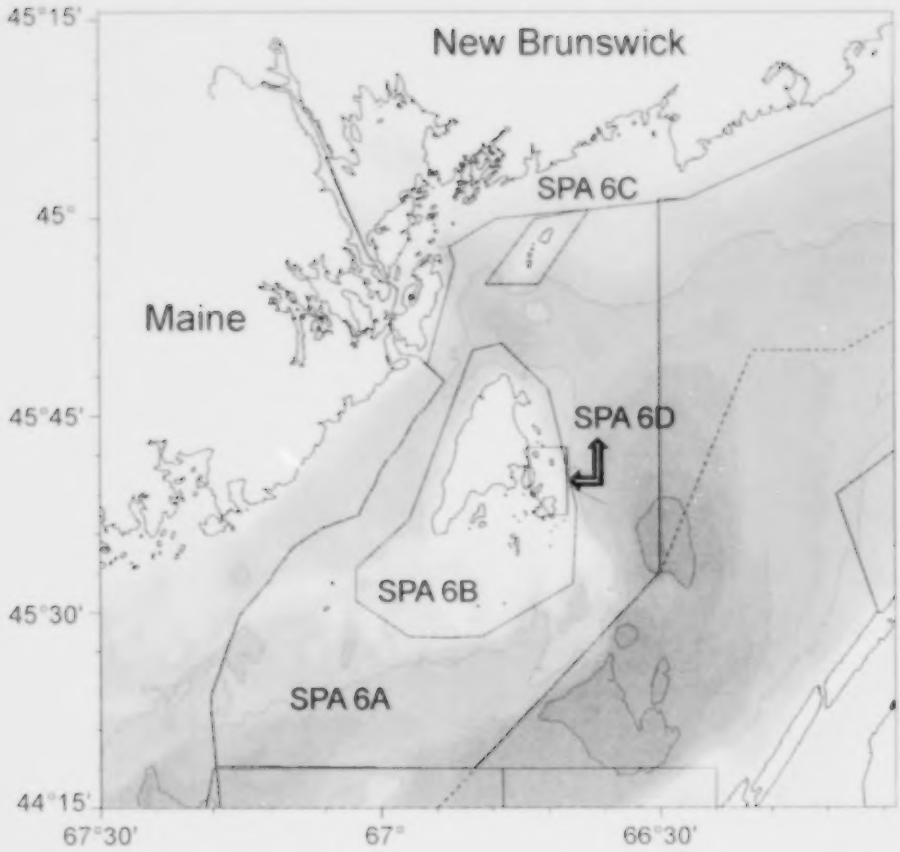

Fig. 66. Map of Scallop Production area (SPA) 6 in the Bay of Fundy.

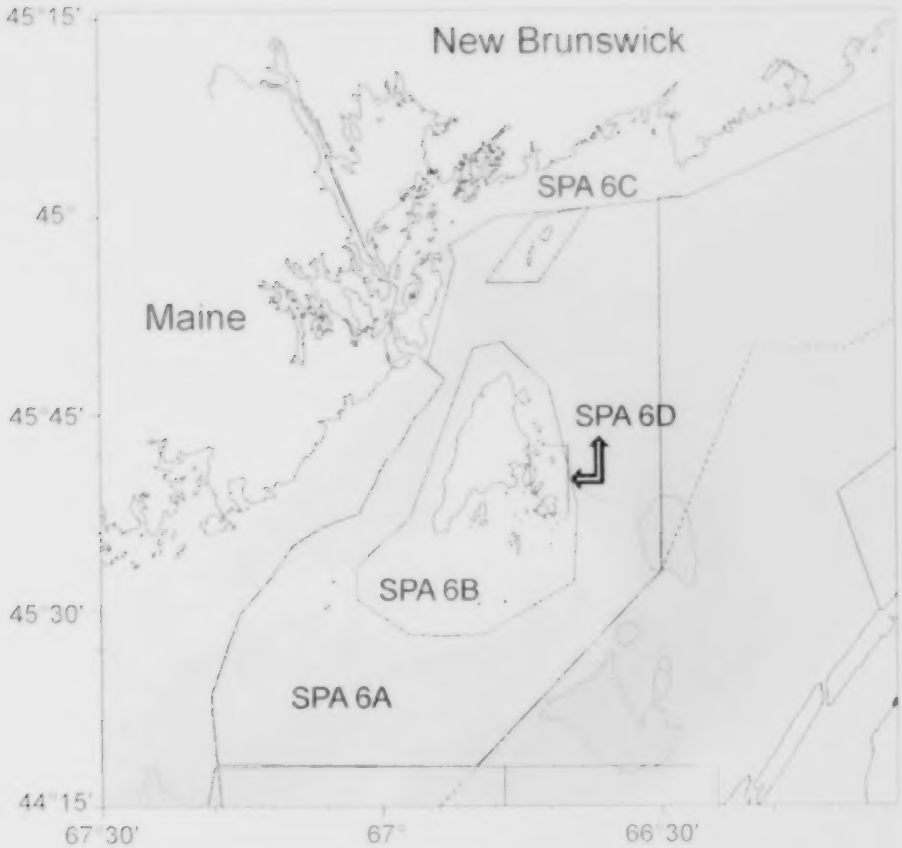

Fig. 66. Map of Scallop Production area (SPA) 6 in the Bay of Fundy

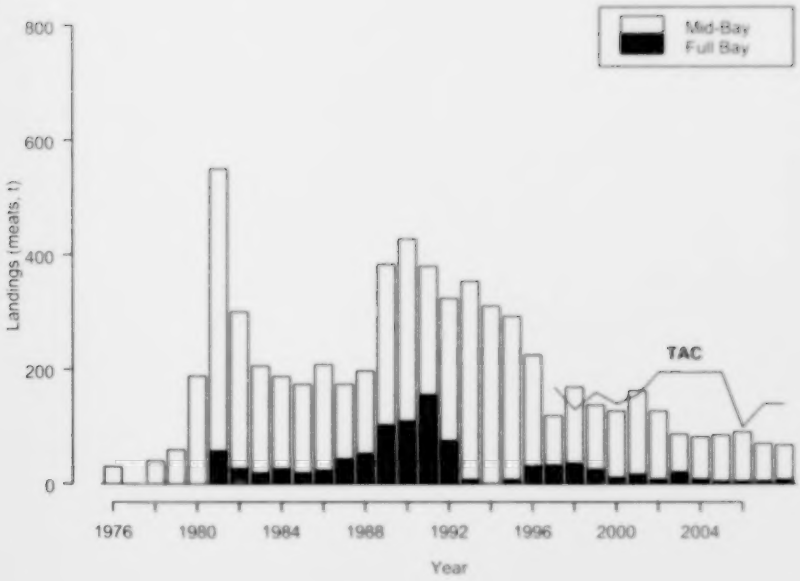

Fig. 67. Scallop landings (meats, t) in Scallop Production Area 6 by fleet.

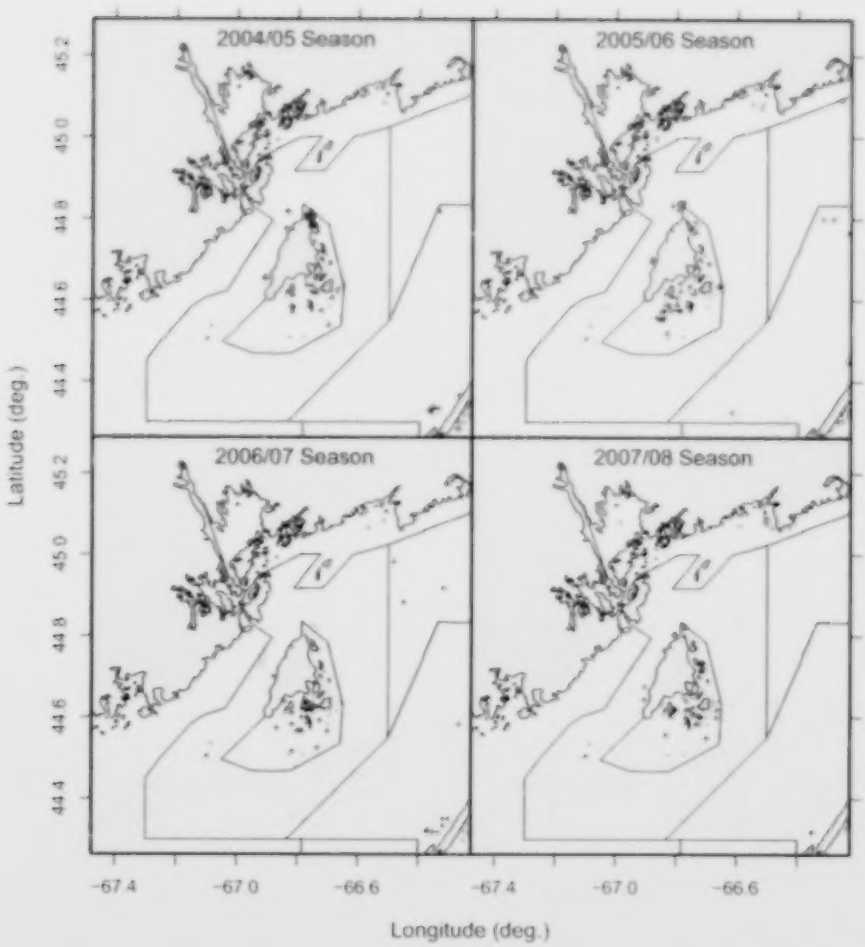

Fig. 68. Fishing locations based upon commercial fishing logs from the Full Bay Fleet in Scallop Production Area 6.

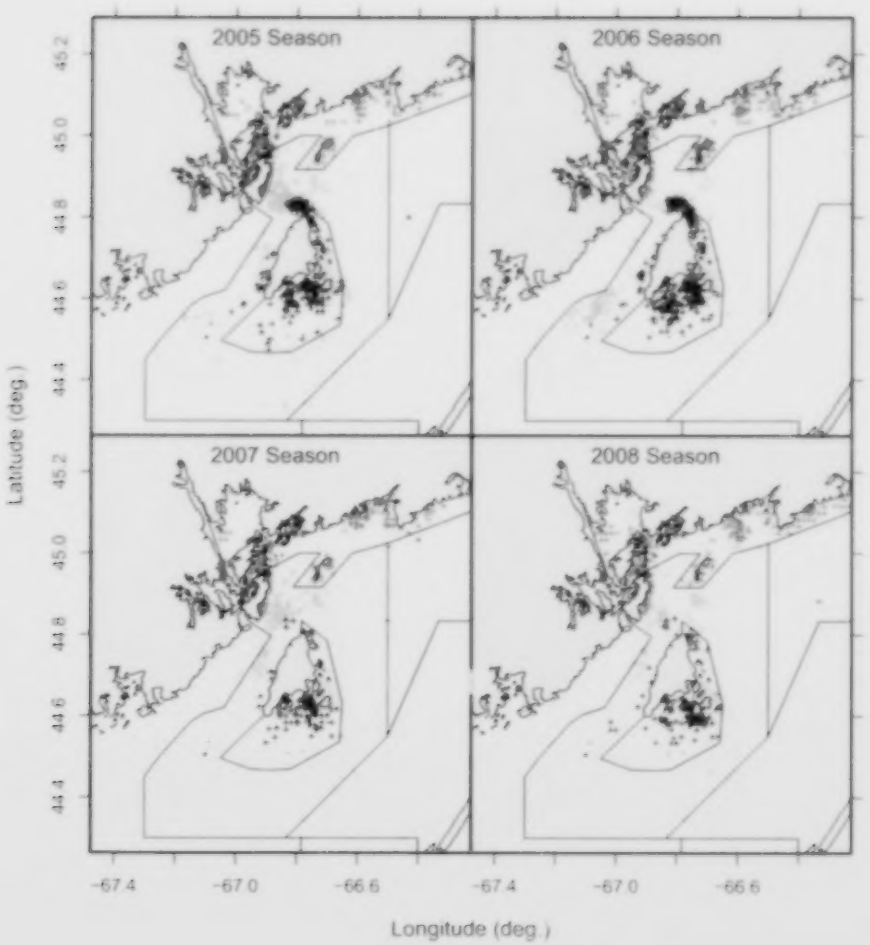

Fig. 69. Fishing locations based upon commercial fishing logs from the Mid-Bay Fleet in Scallop Production Area 6.

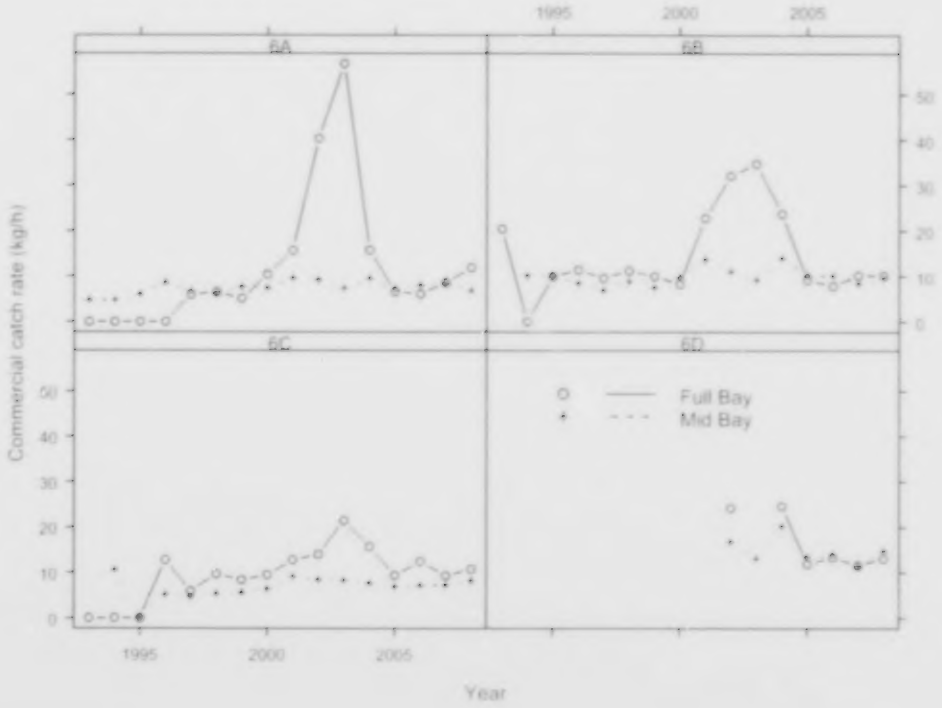

Fig. 70. Commercial catch rate (kg/h) for scallops in Scallop Production Area 6. Top left: SPA 6A. Top right: 6B. Bottom left: 6C. Bottom right 6D (Duck Island Sound).

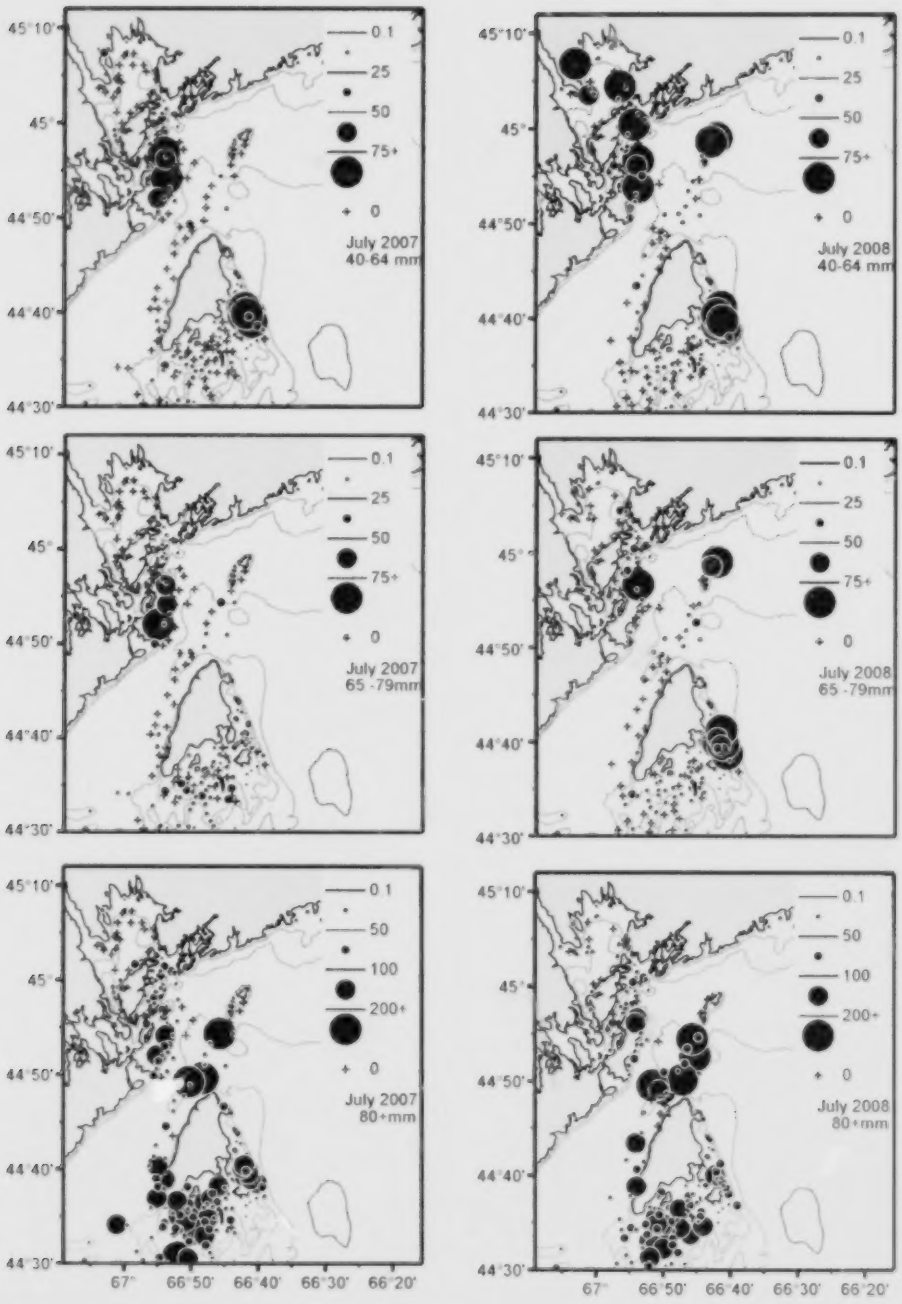

Fig. 71. Spatial distribution of scallop catches from the July 2007 and 2008 surveys of Scallop Production Area 6. Top row: 40–64 cm shell height; middle row: 65–79; bottom row: ≥80 mm.

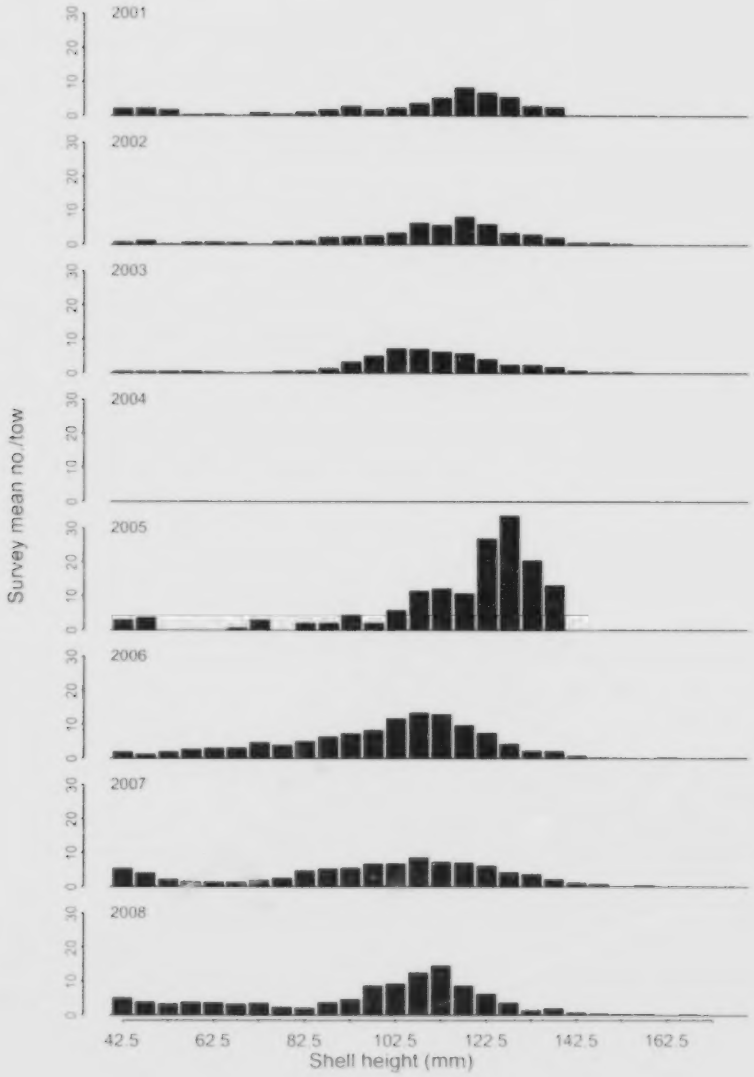

Fig. 72. Comparison of shell height frequencies from the 2001 to 2008 surveys of SPA 6A. No survey was conducted in 2004 and the 2005 survey consisted of only 2 tows.

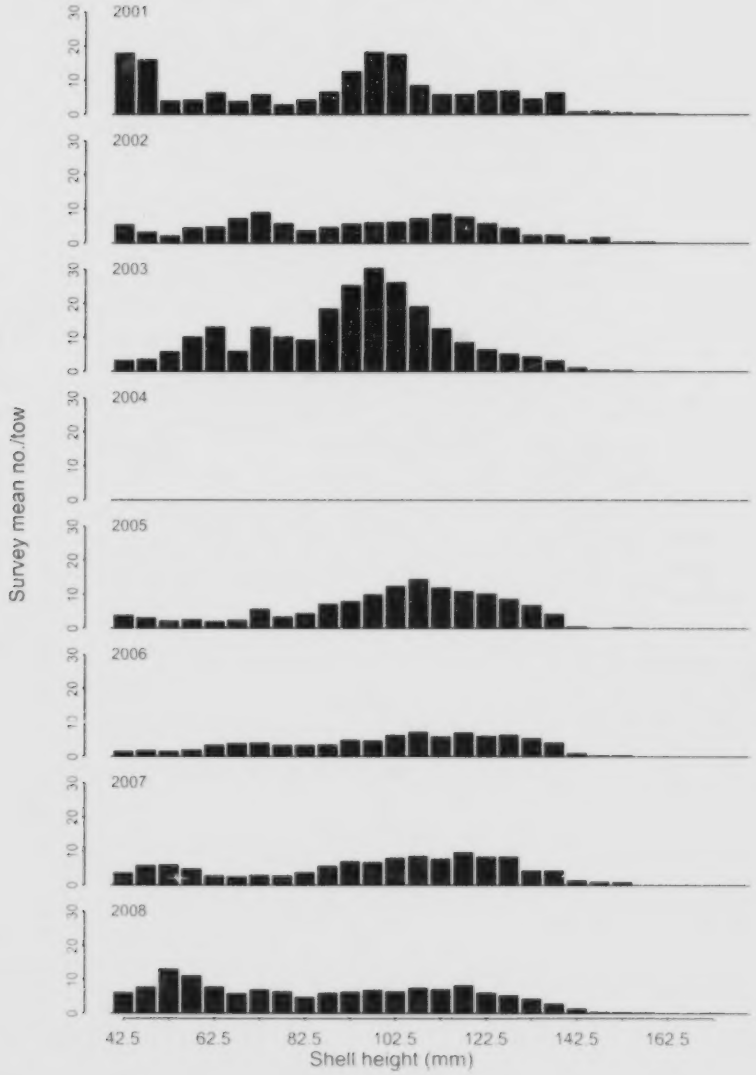

Fig. 73. Comparison of shell height frequencies from the 2001 to 2008 surveys of SPA 6B. No survey was conducted in 2004.

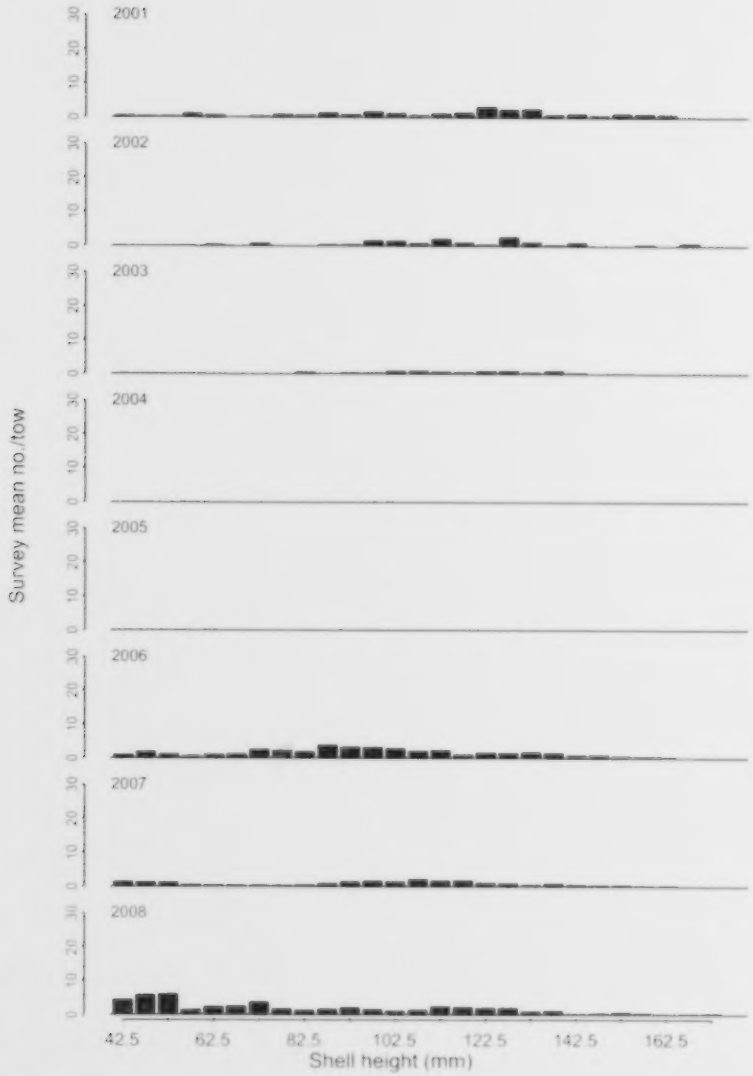

Fig. 74. Comparison of shell height frequencies from the 2001 to 2008 surveys of SPA 6C. No survey was conducted in 2004 or in 2005.

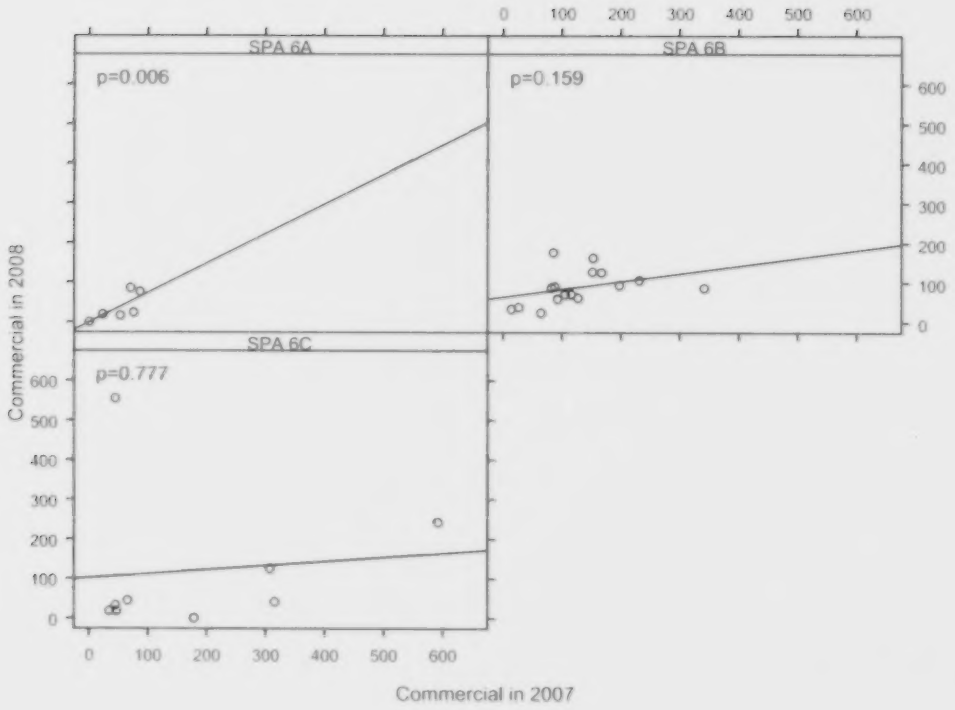

Fig. 75. Comparing numbers of commercial size scallops (≥80 mm shell height) caught in 2007 and 2008 in the survey stations common to both of the surveys in SPA 6. Solid line indicates 1:1 line.

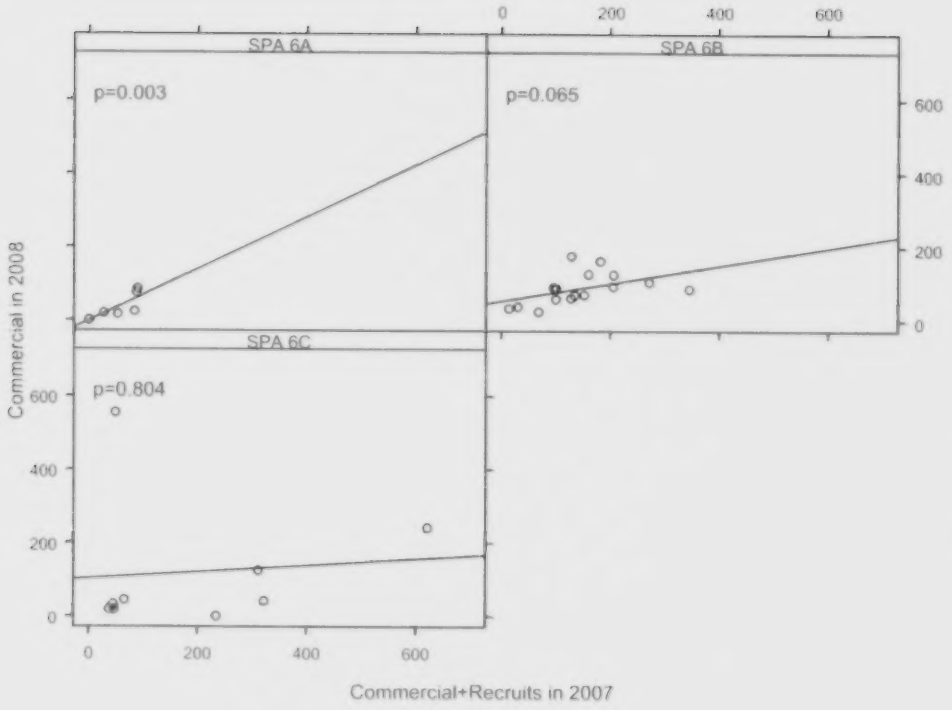

Fig. 76. Comparing numbers of commercial size scallops (≥80 mm shell height) and recruits (65 to 79 mm shell height) caught in 2007 and commercial size scallops 2008 in the survey stations common to both of the surveys in SPA 6. Solid line indicates 1:1 line.

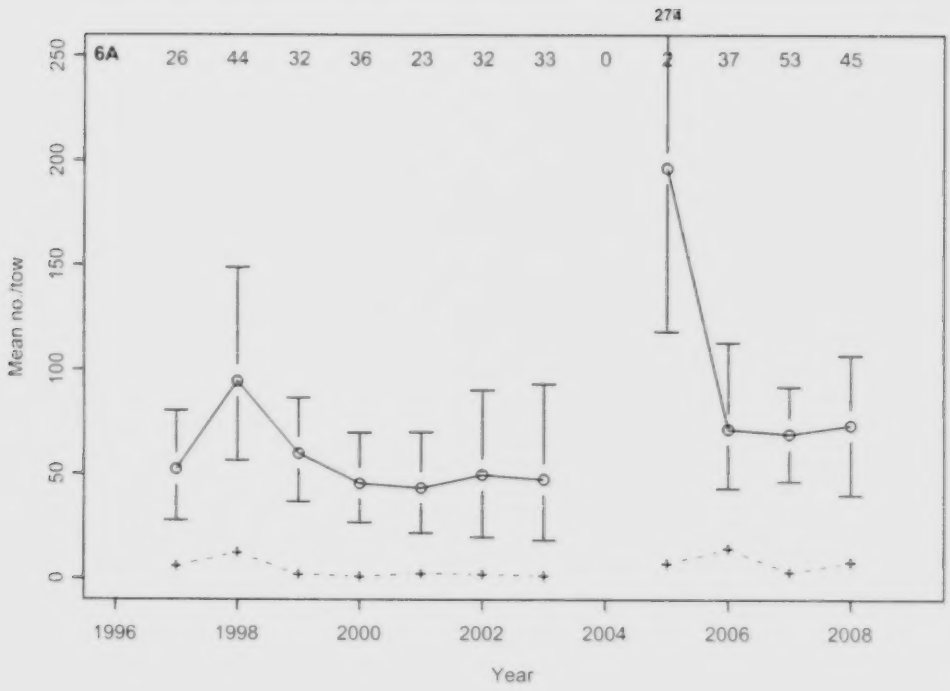

Fig. 77. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6A. Upper and lower limits refer to 95 percent bootstrap limits for surveys from 1996 to 2005. Limits for the double sampling estimates for 2006 to 2008 are calculated as $\pm 2\times$ standard error of the mean. The number of tows completed each year are given across the top of the graph.

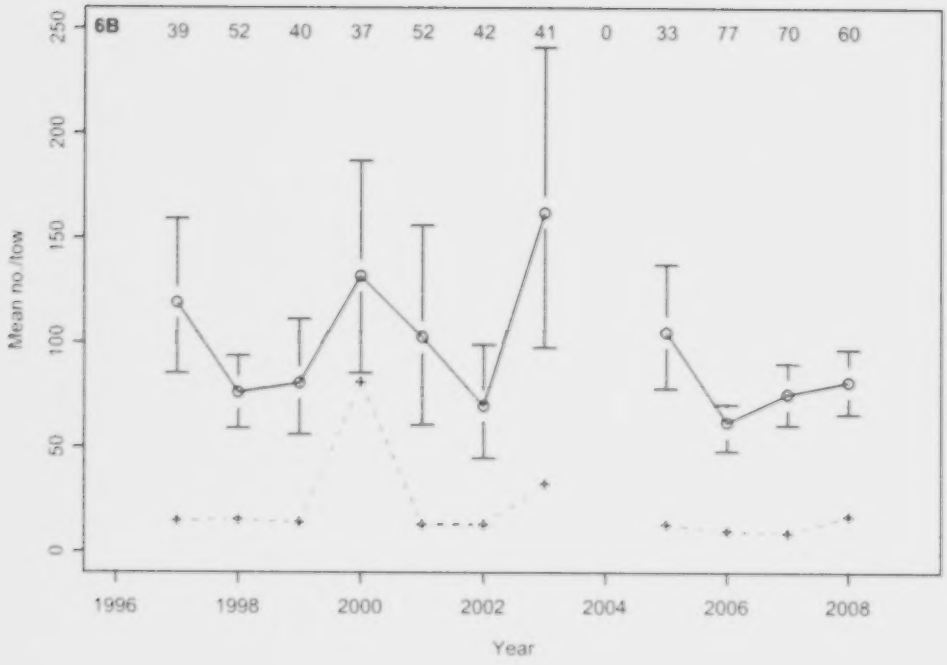

Fig. 78. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6B. Upper and lower limits refer to 95 percent bootstrap limits for surveys from 1996 to 2005. Limits for the double sampling estimates for 2006 to 2008 are calculated as $\pm 2\times$ standard error of the mean. The number of tows completed each year are given across the top of the graph.

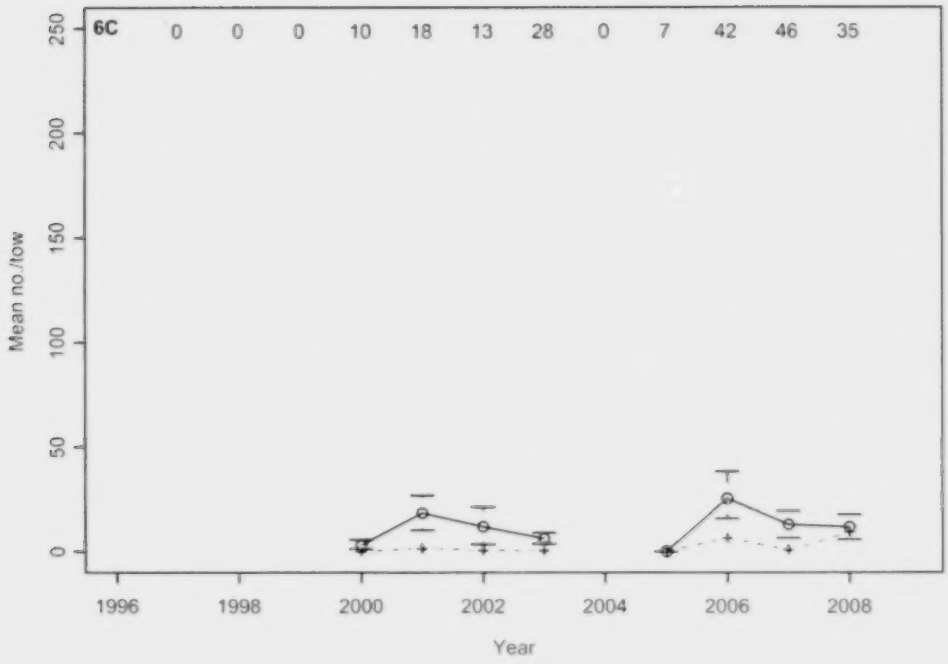

Fig. 79. Trends in survey estimates of mean number per tow of commercial size scallops (shell height $\geq$ 80 mm) and recruits (see text for definition) from research vessel surveys of Scallop Production Area 6C. Upper and lower limits refer to 95 percent bootstrap limits for surveys from 1996 to 2005. Limits for the double sampling estimates for 2006 to 2008 are calculated as $\pm 2\times$ standard error of the mean. The number of tows completed each year are given across the top of the graph.